CEER

Council of European Energy Regulators

6TH CEER BENCHMARKING REPORT ON THE QUALITY OF ELECTRICITY AND GAS SUPPLY

2016

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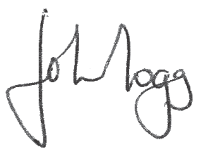
PREFACE

European energy regulators are committed to promoting well-functioning and competitive energy markets in Europe in order to ensure that consumers receive fair prices, a wide choice of suppliers and the best quality of supply. In this Report, the Council of European Energy Regulators (CEER) focuses on monitoring the quality of electricity and gas supply, which constitutes an essential tool in the overall supervision of well-functioning energy markets.

CEER produced five Benchmarking Reports since 2001 that provide an in-depth survey and analysis of the quality of electricity supply. In addition, CEER published updates on some of the key data contained in these Reports in 2014 and 2015. In producing these Reports, CEER seeks to provide valuable information on the regulation regarding quality of electricity of supply in 28 EU Member States as well as Norway and Switzerland, with associated recommendations for good regulatory practices that could be adopted in Europe.

We are delighted to see that our work in providing an extensive analysis of quality of supply issues continues to develop. Expanding on previous Reports, this 6th CEER Benchmarking Report covers not only electricity supply indicators but also gas continuity and quality of supply covering the EU, Norway and Switzerland. Moreover, the Report presents several case studies, including case studies on the situation in Algeria and Israel. In continuing with the CEER-ECRB cooperation on improving service quality regulation, the Report also includes a dedicated annex on quality of supply in seven Energy Community contracting parties.

We hope you will find the data and analysis of interest and that the Report is useful for your work. If you would like to obtain more information about any part of the Report, please do not hesitate to contact the CEER Secretariat or your national energy regulatory authority.



The Lord Mogg
CEER President
Brussels, August 2016

EXECUTIVE SUMMARY

Since 2001 the Council of European Energy Regulators (CEER) has regularly undertaken a survey and analysis of the quality of electricity supply in its member and observer countries, the results of which are presented in its Benchmarking Reports. Over the last 15 years, CEER has produced 5 Benchmarking Reports on the quality of electricity supply, as well as updates on the key data published in February 2014 and February 2015.

In an improvement from previous years, this 6th CEER Benchmarking Report covers not only electricity supply indicators but also gas continuity and quality of supply. This Report provides information on the quality of energy supply in 28 EU Member States as well as Norway and Switzerland, with associated recommendations for good regulatory practices which could be adopted in Europe.

The CEER Report addresses 3 major aspects of quality of supply. For electricity, these are the availability of electricity (continuity of supply), its technical properties (voltage quality) and the speed and accuracy with which customer requests are handled (commercial quality). For gas, these are the supply of gas (technical operational quality), its composition (natural gas quality) and, equivalent to electricity, the speed and accuracy of handling customer requests (commercial quality).

Each chapter of the Report presents the results of the benchmarking through the following steps:

- An explanation of the quality aspect and the importance of its regulation;
- A summary of the past CEER work (for the electricity chapters);
- Specific details on which indicators are monitored as well as a review of how the specific aspects are monitored and regulated; and
- Data and results available from the monitoring and regulation with respect to the responding countries.

The overall goals of quality of supply regulation are to guarantee a good level of continuity of supply, voltage quality, quality and good services for energy consumers across Europe. These goals were considered in the Report's findings and recommendations.

Continuity of Supply

Electricity continuity of supply (CoS) is monitored in all responding countries (30); nevertheless, differences exist in the type of interruptions monitored as well as in the indicators and procedures for data collection and analysis used. The data in the Report demonstrates that 5 countries (Croatia, Greece, Hungary, Romania and Spain) experienced a decrease in the number of planned and unplanned long interruptions in the monitored years up to 2014. Overall, with respect to the number of long interruptions per year (excluding exceptional events) one can observe over recent monitored years either constant quality levels or a general tendency towards a slight increase in quality in nearly all countries. Regarding minutes lost due to planned and unplanned interruptions, large variations exist among responding countries, with the number of minutes lost ranging from 10 to 500 minutes lost per year for planned interruptions and 10 to 1,100 minutes per year for unplanned interruptions.

The chapter on CoS also explores regulatory incentive regimes implemented at system level and single-user level in the responding countries. Nearly two thirds of countries offer individual compensation to network users when standards are not met. Individual compensation is however not in place in Austria, Croatia, Cyprus, Denmark, Germany, Latvia, Luxembourg, the Slovak Republic and Switzerland. In addition to compensation for failing to meet standards, there are also schemes in Ireland and Great Britain for worst-served customers.

In order to further facilitate the comparison of national continuity data Europe-wide, CEER recommends in this Report the harmonisation of CoS indicators, data collection procedures and the methodology to calculate the values of CoS. Moreover, the monitoring of CoS should be expanded to include incidents at all voltage levels in interruption statistics in all countries, and short interruptions should be monitored across Europe. NRAs should also implement adequate incentive schemes for maintaining or improving general continuity levels at the distribution and transmission level.

Voltage quality

Given the answers from 27 countries, the Report shows that half of responding NRAs possess powers and duties to define voltage quality regulation alone or together with other competent authorities. The exact duties and powers the NRA has in voltage quality regulation has an impact on the role the NRAs takes in regulation of power quality, as well as in awareness and education.

In 6 of the reporting countries, either the DSO or the TSO has an obligation to inform end-users about past or expected future voltage quality levels. Upon receipt of a customer complaint regarding the voltage quality at the costumer's connection point, the DSO or TSO is, in several countries, obliged to perform measurements to verify the levels of all relevant voltage quality parameters. In addition, a voltage quality monitor is provided to customers wanting to monitor voltage quality at their connection point. The Report shows that in countries where smart meters have been rolled-out, they are in most cases able to monitor voltage quality.

Although the 2010 European standard EN 50160 remains the basic instrument for voltage quality assessment, some countries have implemented additional requirements in their national legislation. This is mainly due to the fact that the 2010 version of the standard does not cover extra high voltage levels and that some countries seek to implement stricter limits than the standard.

The Report also reveals that a number of countries have introduced legislation related to emissions by individual customers and have identified the concept of responsibility sharing for adequate voltage quality between the network operator, the customer and the manufacturer.

Finally, the voltage chapter includes a case study on voltage quality regulations in Israel where the EN 50160 standard is considered acceptable for the country's electrical grid.

Based on the findings, CEER recommends to accurately identify the responsibility for voltage disturbances according to the concept of responsibility sharing between the network operator, the customer and the manufacturer. Furthermore, CEER recommends publishing the monitored voltage quality data and increasing awareness of how voltage quality impacts on the network and on customers.

Gas technical operational quality

Network users expect a high continuity of supply level at an affordable price in the case of both electricity and gas. The fewer the interruptions and the shorter these interruptions are, the better the continuity is from the viewpoint of the network user. Therefore, one of the roles of network operators is to optimise the continuity performance of their distribution and/or transmission network in a cost effective manner. In the case of gas, one single interruption can lead to a high risk of safety and therefore the efforts of network operators to avoid any interruption are greater than in electricity. Indeed, the Report shows that there are considerably less interruptions in the gas sector than in electricity. Nevertheless, the gas sector experiences longer interruptions than electricity.

Technical safety plays a very important role in the gas sector; however, European countries have adopted varying approaches and regulations for networks' safety. Only 4 responding countries have introduced risk indexes, which seek to define an optimal approach to the operation and recovery of gas facilities in terms of ensuring their safe, reliable and economic operation. Nevertheless, this is not subject to regulation. Currently, a specific financial incentive scheme aimed at improving the safety of gas networks exists only in Italy.

Network losses are an inevitable consequence of transporting gas across the distribution network; nevertheless, their magnitude should be minimised. Yet, only half of responding NRAs use a methodology for computing network losses in gas networks and only half have a regulation n place aimed at reducing network losses.

CEER recommends expanding the coverage of monitoring of continuity of gas supply and safety indicators so that comparisons are possible across more countries in the future. CEER further recommends that, for the purpose of effective comparison, a definition of a basic set of indicators for gas technical operational quality is adopted.

Natural gas quality

The number of indicators monitored by NRAs demonstrates that countries pay close attention to natural gas quality. If gas quality is not met, it is important to know who is responsible in any given situation. For the majority of countries, the TSO and shipper are financially and/or legally responsible for natural gas quality. Since gas resources are exchangeable on the market, the question of shared responsibilities of transporters between 2 bordering countries is important; however, opinions among countries vary between those that consider responsibility to be at the TSO exit point and those that consider it to be shared between both TSOs on either side of an interconnection point.

The European Commission has signalled its intent to amend the Interoperability Network Code to include the European Committee for Standardisation (CEN) Standard. If the CEN standard was made binding, TSOs might need to invest in costly treatment processes in order to accept gas that would now be outside of specification. The alternative would be to refuse gas that does not meet the CEN standard, thus potentially creating future security of supply issues. CEER recommends that any attempt to harmonise gas quality firstly clarifies the problem at hand, then considers the impacts of making the standard binding, and lastly avoids having any unintended consequences on, inter alia, security of supply.

Electricity and gas commercial quality chapters

The findings of the electricity and gas commercial quality chapters are similar in that they show an increased focus by NRAs on the quality of the services provided to customers.

Looking at electricity commercial quality, performance levels have been stable or have slightly increased overall in the identified years to 2015. This is the case for the connection performance indicators, where 8 countries perform better than the overall average and others have registered an improvement in their performance. Similarly, the reported non-compliance indicators related to customer care are for most countries relatively low.

Regarding metering and billing, in general performance results are particularly good for the time for restoration of power supply following disconnection due to non-payment. The Czech Republic, Greece, Hungary, Portugal and Slovenia have performance rates over 98% for the 2010-2014 period.

The Report shows that there is room for progress especially regarding the level of gas commercial quality. Out of the responding countries, only 3 reach the value of their indicator regarding the provision of an answer to customers' queries/requests. The punctuality of operators with respect to planned appointments with customers is a major commercial quality issue, with Austria and Italy demonstrating good performances in this regard. The chapter shows that compensation paid to the customer for non-compliance exists in some countries but not on a sufficient scale. Some countries also apply automatic compensation in the case of non-compliance for certain indicators. CEER recommends that NRAs should ensure greater protection through Guaranteed Indicators with automatic compensation for customers.

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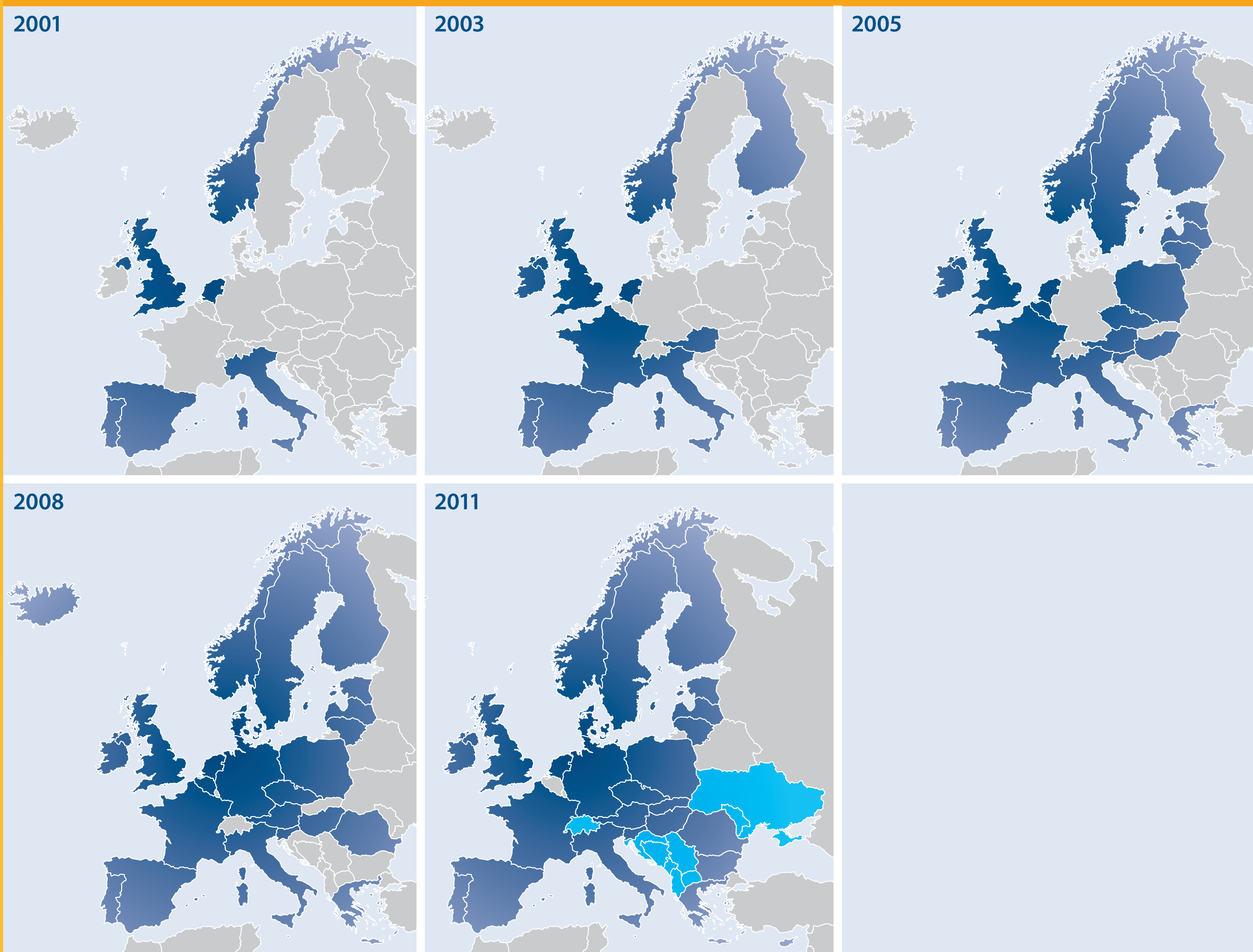
FIGURE 1.1 ACTIVE CONTRIBUTION TO THE CEER BENCHMARKING REPORTS OVER ITS 5 EDITIONS (2001-2011)



1.1. BACKGROUND

The Council of European Energy Regulators (CEER) periodically surveys and analyses the quality of electricity supply in its member and observer countries. These surveys and analyses take the form of CEER Benchmarking Reports on Quality of Electricity Supply, hereafter Benchmarking Reports. The first report was issued in 2001 [1], followed by the 2nd, 3rd, 4th and 5th editions in 2003, 2005, 2008 and 2011 respectively [2], [3], [4], [5]. Moreover, updates on the key data were published in February 2014 and 2015. For the first time, this 6th Benchmarking Report also examines and analyses the quality of gas supply.

The publication of these Reports has facilitated the availability of information on the regulation of quality of supply and its implications in each country. In addition, the Reports provide good practices for regulating the quality of supply in electricity grids, which have been adopted by many European countries. Since the first edition, the benchmarking exercise has steadily spread throughout Europe as displayed in Figure 1.1.

1.2. COVERAGE

This Benchmarking Report includes data from National Regulatory Authorities (NRAs) from EU Member States as well as Norway and Switzerland, as illustrated in Figure 1.2. In addition, a total of 7 countries from the Energy Community Regulatory Board (ECRB) – Albania, Bosnia and Herzegovina, Former Yugoslav Republic of Macedonia, Kosovo, Montenegro, Serbia and Ukraine – have also completed the benchmarking exercise the results of which can be found in Annex titled "Quality of Electricity Supply in the Energy Community". Lastly, to widen the geographical scope of the Report, case studies from the members of the Mediterranean Energy Regulators (MedReg), Algeria and Israel, are part of this Report.

1.3. STRUCTURE

This 6th Benchmarking Report addresses 3 major aspects of quality of supply. For electricity, these are its availability (continuity of supply), technical properties (voltage quality) and the speed and accuracy with which customer requests are handled (commercial quality). These elements are treated in Chapter 2, 3 and 4, respectively. For gas, these are its supply (technical operational quality), composition (natural gas quality) and commercial quality, which are treated in Chapter 5, 6 and 7, respectively.

Each chapter presents the benchmarking results in the following steps:

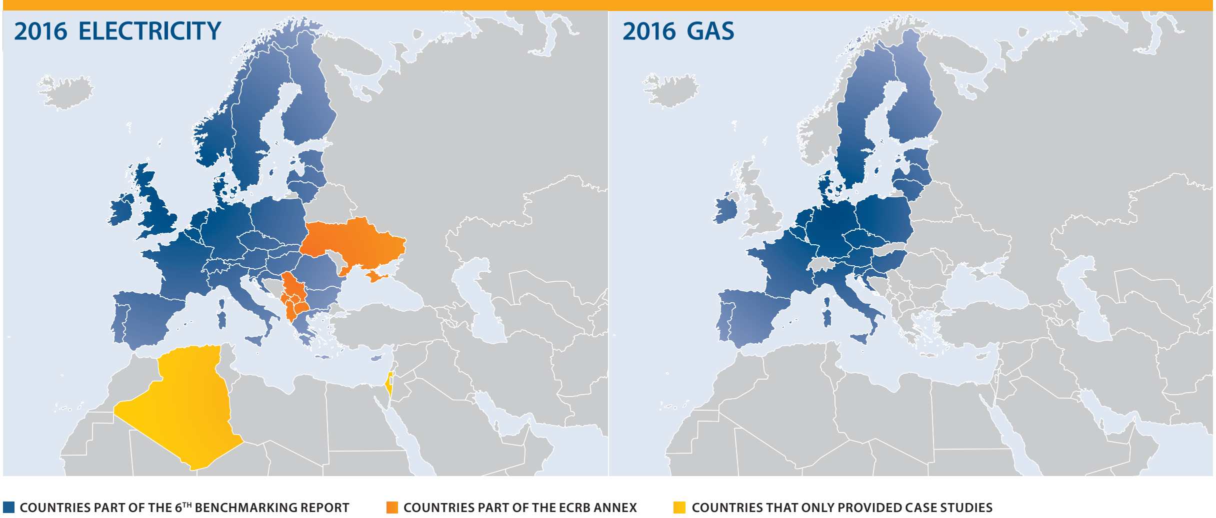
- An explanation of the quality aspect and the importance of its regulation;
- A summary of the past work (for the electricity chapters) of the European Energy Regulators;
- Specific details on the following topics:
  - A review of what is monitored;
  - A review of how the specific aspects are monitored and regulated; and
  - Actual data and results.

A more detailed analysis of practices in certain countries was included in the form of case studies, which illustrate the varying approaches to the regulation of quality of supply and reflect the conditions specific to each studied country.

1.4. CONCLUSIONS

The general goal of the quality of supply regulation is to guarantee a good level of continuity of supply, voltage quality, gas quality and good services for consumers across Europe. These goals were considered in findings and recommendations at the end of the chapters that reflect the key information and aspects concerning the covered topics. CEER members and observers as well as the additional countries included in the Report should consider the implementation of these recommendations.

FIGURE 1.2 ACTIVE CONTRIBUTION TO ELECTRICITY AND GAS CHAPTERS



02

ELECTRICITY – CONTINUITY OF SUPPLY

2.1. WHAT IS CONTINUITY OF SUPPLY AND WHY IS IT IMPORTANT TO REGULATE IT

Continuity of supply concerns interruptions in electricity supply and focuses on the events during which the voltage at the supply terminals of a network user drops to zero or nearly zero[1]. Continuity of supply can be described by various quality dimensions. The ones most commonly used are number of interruptions, unavailability (interrupted minutes) and energy not supplied (ENS) per year.

Network users expect a high continuity of supply[2] at an affordable price. The fewer the interruptions and the quicker the return of electricity supply, the better the continuity from the network user's point of view. Therefore, one of the roles of network operators is to optimise the continuity performance of their distribution and/or transmission network in a cost effective manner. The role of the NRAs is to ensure that this optimisation is carried out in a correct way, taking into account users' expectations and their willingness to pay.

Continuity of supply indicators are traditionally important tools for making decisions on the management of distribution and transmission networks. Regulatory instruments now mostly focus on accurately defined continuity of supply indicators of frequency of interruptions, their duration, and energy not supplied due to interruptions. These instruments normally complement incentive regulation, which (either in the form of price or revenue-cap mechanisms) is commonly used across Europe at present. Incentive regulation provides a motivation to increase economic efficiency over time. However, it also carries a risk of network operators refraining from carrying out investments and proper operational arrangements for better continuity, in order to lower their costs and increase their efficiency. To account for this drawback in incentive regulation, a large number of European NRAs adopt additional regulatory instruments to maintain or improve continuity of supply.

2.2. MAIN CONCLUSIONS FROM PAST WORK ON CONTINUITY OF SUPPLY

The 1st Benchmarking Report published in 2001 identified the 2 main features of continuity of supply regulation as:

- guaranteeing that each user can be provided with at least a minimum level of quality; and
- promoting quality improvement across the system.

The comparative analysis of available measurement and continuity of supply regulation in the 1st Benchmarking Report shows that NRAs have generally approached continuity issues by first looking at long interruptions affecting low voltage (LV) network users and treating planned and unplanned interruptions separately. In several countries, both the number and the duration of interruptions were available. However, the choice of the indicator used varies by country. Moreover, many countries record short interruptions as well as long interruptions. Different approaches to continuity of supply regulation combined with different geographical, meteorological and network characteristics, make benchmarking of actual levels of continuity of supply difficult. CEER urged NRAs in the 1st Benchmarking Report to pay attention to implementation and control issues and identified the most important of these:

- regular internal audits by distribution companies and sample audits by the NRA; and
- accuracy and precision indicators to assist in auditing and to inform decisions about sanctions.

In the 2nd Benchmarking Report, the number of countries included in the comparison was extended and the comparisons were more detailed. Distinctions were made between planned and unplanned interruptions, different voltage levels and load density areas and interruptions were classified by their cause. It was noted that further harmonisation of data and definitions between NRAs remained necessary. The 2nd Benchmarking Report also concluded the level of quality of supply had not decreased significantly in European countries even after the privatisation of utilities, increasing supply competition, price-cap regulation for monopolistic activities and legal unbundling of businesses.

1. According to EN 50160.
2. The terms "availability of electricity supply" and "reliability of supply" can be used interchangeably with continuity of supply. However, this report adopts the term "continuity of supply" as in the previous CEER Benchmarking Reports.

A number of encouraging trends were also observed in the 3rd Benchmarking Report, such as:

- The duration of unplanned interruptions showed significant improvement (downward trend) for most countries;
- The number of unplanned interruptions showed improvement (downward trend) for most countries;
- Excluding exceptional events from unplanned interruption performance figures highlighted the significant improvements made by many European countries in terms of the duration and the number of interruptions;
- Countries with previously low levels for duration and number of interruptions were able to make further improvements; and
- The number of short interruptions had generally not risen despite an increased move to automation and remote control techniques.

CEER concluded in the 2nd and 3rd Benchmarking Reports that audit procedures had been put in place in almost all countries that adopted reward/penalty schemes, as measurement rules and that audit procedures become more important when some kind of economic incentive is used for continuity of supply.

The 4th Benchmarking Report introduced precise definitions of continuity indicators in order to ensure an appropriate homogeneity between European countries. Very detailed chapters on exceptional events and a short presentation of on-site audits on continuity data were also added.

Between the 4th and the 5th Benchmarking Reports, CEER commissioned a consultancy report: "Study on estimation of costs due to electricity interruptions and voltage disturbances" elaborated by SINTEF [6] and published "Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances" (2010) [7]. 2 key messages emerged:

- Results from cost-estimation studies on costs due to electricity interruptions are of key importance for setting proper incentives for continuity of supply; and
- The CEER Guidelines of Good Practice (GGP) should be used as a reference when performing a nationwide cost-estimation study, always taking into account country-specific issues and needs.

CEER representatives contributed significantly to the CENELEC technical report CLC/TR 50555:2010 "Interruption indexes" [8], issued in 2010, covering guidance on how to calculate continuity of supply indices as well as recommendations on a set of indices System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI) and Momentary Average Interruption Frequency Index (MAIFI) suitable for pan-European benchmarking of distribution network performances. The report recognised its shortcoming in not addressing rules on the aggregation of interruptions, in particular short interruptions and proposed to describe aggregation rules in a second version of the technical report.

In the 5th Benchmarking Report, a case study from Switzerland was included in the main document and 9 countries from the Energy Community Regulatory Board (ECRB) were included as an annex to the report. The report offered a more detailed look into the correlation between interruptions and percentage of underground cables; level of detail in the indicators; contributions to duration and frequency of interruptions based on voltage level and differences between interruptions in urban, suburban and rural areas of certain EU Member States. In addition, descriptions of quality incentive schemes were presented for many countries.

2.3. STRUCTURE OF THE CHAPTER ON CONTINUITY OF SUPPLY

The chapter on continuity of supply takes a closer look at the monitoring practices and indicators used in the responding countries. After a detailed analysis of continuity, the chapter investigates existing regulation at system level and at single-user level (including standards and incentives), and concludes with findings and recommendations on continuity of supply.

The chapter is based on input from 30 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden and Switzerland. Moreover, case studies from the Czech Republic and MedReg members, Algeria and Israel, are also included.

2.4. CONTINUITY OF SUPPLY MONITORING

Continuity of supply refers to the availability of electricity to all network users. All countries that participated in this Benchmarking Report stated that they monitor continuity of supply in their electricity networks. However, there are significant differences in monitoring across the EU Member States.

Differences arise in the type of interruptions monitored, the reported level of detail as well as the interpretation of various indicators. This section presents the methods used for monitoring in different countries.

2.4.1. Definitions and monitoring of interruptions based on duration

In the following table (Table 2.1), definitions of interruptions of different duration are reported for various countries. It is important to note that some countries do not define all types of interruptions, such as transient, while others consider transient interruptions to be included in short interruptions.

The provided definitions of short interruptions reveal that there are cases when boundaries between interruptions of different duration are blurred, as there is no clear distinction between long and short interruptions. Sometimes only interruptions above certain minimum duration are defined (e.g. 5 seconds in the Netherlands or 1 minute in Denmark) but the definition itself does not distinguish between different lengths of interruptions. Most of the countries that differentiate between long and short interruptions are in line with the EN 50160 standard regarding voltage characteristics in public distribution systems. Long interruptions are monitored in all countries that answered the questionnaire. Out of these countries, 12 also monitor short or transient interruptions.

TABLE 2.1 DEFINITIONS OF LONG, SHORT AND TRANSIENT INTERRUPTIONS

Country	Transient interruption	Short interruption	Long interruption
Austria	Not defined	1 sec<T≤3 min	T>3 min
Belgium	Same category as short	T<3 min	T≥3 min
Bulgaria	T<1 sec	T<3 min	T>3 min
Croatia	Not defined	1,5 sec≤T≤3 min	T>3 min
Cyprus	Not defined	Not defined	Not defined
Czech Republic	20 msec<T≤1 sec	1 sec<T≤3 min	T>3 min
Denmark	No distinction between long and short interruptions. An interruption has duration of at least 1 minute (1).	No distinction between long and short interruptions. An interruption has duration of at least 1 minute (1).	No distinction between long and short interruptions. An interruption has duration of at least 1 minute (1).
Estonia	Not defined	Not defined	T>3 min
Finland		T<3 min	T≥3 min
France	T<1 sec	1 sec≤T≤3 min	T>3 min (2)
Germany	T≤1 sec	1 sec< T≤3 min	T>3 min
Great Britain	Same category as short	T<3 min	T≥3 min (3)
Greece	Not defined	T≤3 min	T>3 min
Hungary	T≤1 sec	1 sec<T≤3 min	T>3 min
Ireland	Not defined	Not defined	T≥3 min (4)
Italy	T≤1 sec	1 sec<T≤3 min	T>3 min
Latvia	Not defined	T≤3 min	T>3 min
Lithuania	Not defined	T<3 min	T≥3 min
Luxembourg		T≤3 min	T>3 min
Malta	No such classification used. All interruptions are recorded.	No such classification used. All interruptions are recorded.	No such classification used. All interruptions are recorded.
The Netherlands	Not defined	No distinction between long and short interruptions. An interruption has duration of at least 5 seconds.	No distinction between long and short interruptions. An interruption has duration of at least 5 seconds.
Norway	Included in short (5)	T≤3 min	T>3 min
Poland	T<1 sec	1 sec≤T<3 min	T>3 min
Portugal	Not defined	1 sec≤T≤3 min	T>3 min
Romania	T≤1 sec	1 sec<T≤3 min	T>3 min
Slovak Republic	Not defined	T<3 min	T>3 min
Slovenia	Not defined	T≤3 min	T>3 min
Spain	Not defined	T≤3 min	T>3 min
Sweden		100 msec≤T≤3 min	T>3 min
Switzerland	T<1 sec	1 sec≤T≤3 min	T>3 min

(1) All interruptions lasting 1 minute or longer are monitored.
(2) Until 2010, it was duration ≥3 min.
(3) This excludes re-interruptions to customers that have already been interrupted during the same incident.
(4) Up to and including 2010, this definition was T≥1 minutes. For 2011 onwards, the definition was changed to T≥3 minutes.
(5) This definition is not used. Short interruptions start at zero.

2.4.2. Planned and unplanned interruptions

Most countries use separate classifications for planned (notified) and unplanned interruptions. The concept "planned interruption" is cited in EN 50160 [16] (the term "prearranged interruption" is used) as an interruption for which network users are informed in advance, typically due to the execution of scheduled works on the electricity network. Most countries consider advance notification to affected network users to be sufficient and necessary for an interruption to be classified as planned.

The majority of countries have a definition for planned interruptions. Whereas there is a general agreement on this definition, the requirement for advance notice varies strongly among countries (between 24 hours and 50 days). In some cases, the rules are less strict and depend on an agreement between the network operators and customers. Many countries with lower share of planned interruptions in the overall duration of interruptions make use of live works, portable generators and reconfiguration of networks to prevent such interruptions or mitigate their impact [9]. Definitions of planned and unplanned interruptions as well as rules for treatment of planned interruptions can be found in Table 2.2.

TABLE 2.2 PLANNED AND UNPLANNED INTERRUPTIONS – DEFINITIONS AND RULES

Country	Planned interruption	Unplanned interruption	Rules for planned interruptions
Austria	Interruptions for which the grid user has to be informed in advance.	Interruptions caused by lasting or temporary disturbances, mainly related to component malfunction or external disturbances.	The DSO has to inform the affected grid users about the start and duration at least 5 days before the planned interruption. In case of individual mutual agreements, the notification can be shorter.
Belgium	EHV / HV: the interruption planning process and notification milestones towards customers are detailed in the connection contract. The interruption is subject to customer's approval.	EHV / HV: All interruptions caused by unforeseen opening of circuit-breakers.	At the end of every year, the TSO makes a list of all planned interruptions for the following year and notifies the concerned customers at the same time. When the interruption date approaches, the TSO checks whether the interruption is still acceptable under the actual grid conditions 7 weeks before and then each week from 5 to 1 week before the planned interruption. If so, the interruption occurs in consultation with the customer.
Bulgaria	Interruptions for which the grid user has to be informed in advance.	When the customer has not been informed in advance.	For activities which are subject to planning, the company is under the obligation to inform the customer/network users about the time and duration of an electricity supply interruption through the mass media at least 14 calendar days in advance.
Croatia	Interruptions for which the grid user has to be informed in advance.	In case of force majeure or failure.	48 hour individual notice before works for users over 30 kW and 24 hour notice over mass media for users below 30 kW.
Cyprus	Interruptions for which the grid user has to be informed in advance.	An interruption due to unforeseen events like component failures, lightning strikes, excavation activities or incorrect switching actions.	Planned interruptions occur when certain work is required on the network (maintenance, upgrade, etc.) or in the event of significant deficit in generation. There is no minimum time limit for customer notification.
Czech Republic	Interruptions in electricity transmission or distribution network during performance of planned work on transmission or distribution devices according to Energy Act (mainly: maintenance, refurbishing, construction).	All interruptions in electricity transmission or distribution that are not planned (divided: failure under usual weather conditions, failure under unfavourable weather conditions, caused by third-party, forced, extraordinary, interruption outside system).	The TSO has to inform affected customers 50 days in advance, the DSO has to inform affected customers 15 days in advance.
Denmark	At least 48 hour notice to all affected customers.	When the notice is less than 48 hours.	48 hour notice.
Estonia	Planned due to construction, repairing and maintenance works on the network.	Due to unpredictable damages, faults in network.	Rules issued about notice to customers are affected with minimum time-lag requested.
Finland	Interruptions for which the grid user has to be informed in advance.	Unplanned interruptions are not notified to customers in advance.	No rules for planned interruptions by the NRA.
France	An interruption notified in advance to all affected customers with adequate notice.	An interruption not notified in advance to all affected customers or notified with inadequate notice.	On the transmissions network, there is a procedure with different steps of planning starting from 1 year (or even more for important works) to 1 month before the interruption. The last confirmation is given at least 15 days before. On the distribution network, the operator must agree with MV customer on a date for the planned interruption at least 10 days before the date (except in case of emergency). Planned interruptions are notified to small customers (<36 kVA) by press or by individualised information.

Country	Planned interruption	Unplanned interruption	Rules for planned interruptions
Germany	Interruptions with notice or arrangement in advance to the customers.	All other interruptions.	No.
Great Britain	Interruption where notification has been given to affected customers at least 48 hours before the interruption.	Interruption of supply to customer(s) for 3 minutes or longer or any occurrence on the distribution system or other connected distributed generation or transmission system that prevents a circuit or item of equipment from carrying normal load current and where notification has not been given to customers at least 48 hours before the interruption.	At least 48 hour notice should be provided to affected customers – carding customers with the expected interruption duration, etc.
Greece	48 hour notice.		No rules issued by the NRA.
Hungary	Interruptions for which the grid user has to be informed in advance.	When not all affected customers are given an adequate advance notice.	According to the Guaranteed Standards there are 2 different notification rules depending on the power capacity: • with power capacity below 200 kVA customers should be notified 15 days before the planned interruption according to the local practise, e.g. leaflet; • with power capacity of 200 kVA or above, customers should be notified 30 days before the planned interruption in a personal letter if there is no other agreement between the parties.
Ireland	Planned (prearranged) interruptions are those which are caused by the system operator interrupting supply in order to do planned maintenance or construction on the network. Normally, customers are informed in advance of planned interruptions.	In unplanned (accidental) interruptions, which are those caused by permanent (a long interruption) or transient (a short interruption) faults, mostly related to external events, equipment failures or interference, the customer is normally not informed in advance.	A minimum notice of 2 days must be provided.
Italy	An interruption notified in advance to all affected customers with adequate notice.	Any interruption that is different than planned.	Rule for distribution network operators: advance notice of 3 working days from 1 January 2016 (previously: 2 working days). Advance notice reduced to 24 hours in case of interventions after faults or during emergencies.
Lithuania	Interruption, which was informed to the customer on time and in a way set in the legal acts or agreement.	Interruption, which was not informed or informed to the customer later than the time and way set in the legal acts or agreement, except if it was done to ensure the public interests.	By law the customer has to be informed about the interruption not later than 10 days ahead.
Luxembourg	Previous notice of interruption.	No previous notice of interruption, however, if possible, provisional length of interruption has to be communicated to the affected customers.	Network operators are legally bound to inform customers about the date and time of the planned interruption prior to the interruption, as early as possible and by appropriate means.
Malta	An outage of a generating plant or of part of the distribution system other than a forced outage. In practice a planned interruption is one where the customers have been notified in advance.	An interruption where the customers have not been notified in advance.	A 3 day notice must be provided.
The Netherlands	An interruption of which the network operator has informed the affected customers at least 3 working days in advance.	An interruption that is not a planned interruption.	Yes, notice to household customers and industrial customers on the low voltage network must be given at least 3 working days in advance, but no criteria exist relating to the procedure for giving notice. Notice to industrial customers on the medium and high voltage network must be given at least 10 working days in advance and the time of the planned interruption can only be established after consultation with the customer and taking into account the interests of the customer.
Norway	Planned interruptions are called notified interruptions. An interruption is considered notified if customers are informed a reasonable amount of time prior to the interruption and the information has been provided in an appropriate manner.	Unplanned interruptions are called non-notified interruptions. An interruption is considered non-notified if it does not fulfil the requirements for a notified interruption.	The interruption must be notified minimum 24 hours prior to the interruption, but as a main rule 2 business days prior to the interruption. The information shall be provided in an appropriate manner. Trade and industry end-users must be notified individually. If the interruption is not satisfactorily notified, it shall be regarded as a non-notified interruption.

Country	Planned interruption	Unplanned interruption	Rules for planned interruptions
Poland	Classified as prearranged (planned), when network users are informed in advance, to allow for the execution of scheduled works on the distribution system.	Classified as accidental (unplanned), caused by permanent or transient faults, mostly related to external events, equipment failures or interference without notice in advance to the customers.	A minimum of 5 days of prior notice must be provided.
Portugal	Interruption with notice in accordance with the Commercial Relations Code, published by ERSE.	Interruption without notice.	Interruption with notice in accordance with the Commercial Relations Code, published by ERSE. Interruptions for reasons of public interest: the entity responsible for the network must inform, whenever possible, and with a minimum prior notice of 36 hours, the customers which may be affected by the interruption. Interruptions for service reasons: DSOs can agree with customers the best moment for the interruption. If an agreement is not possible, the interruptions must occur, preferentially, on Sundays, between 05:00 hours and 15:00 hours, with a maximum duration of 8 hours per interruption and 5 Sundays per year, per costumer affected. DSO must inform a customer with a minimum prior notice of 36 hours. Interruptions due to costumer responsibility: The supply interruption may only take place following a prior notice of interruption, with a minimum advance warning of 8 days relative to the date when it will occur. If the costumer installation emits perturbations to the network, the operator establishes, in accordance with the costumer, a time period for solving the problem.
Romania	The interruption is considered planned when the customers are informed in advance, usually with 15 calendar days and in special circumstances, critical operation conditions, can however be delayed, with 1 day (24 hours).	The interruption is considered unplanned when the customers are not informed in advance.	Usually the planned interruptions are discussed and planned with the big customers.
Slovak Republic	Not defined.	Interruption by reason of failure or force majeure.	Minimum time for giving notice is 15 days.
Slovenia	According to EN 50160:2010.	According to EN 50160:2010.	Each customer that will be affected must be informed, using written form or any other suitable form, in a timely manner. If the interruption will affect a greater number of customers, the customers must be informed by public notification (by announcement on the local radio, publication on the DSO website, notification by using messaging services (SMS, MMS) etc.) at least 48 hours before the start of the interruption.
Spain	An interruption of continuity of supply declared by Distribution firm previously (72 hours) to Regional Government, and authorised by this institution.	Any interruption not considered as planned interruption.	Planned interruptions must be announced to affected customers giving a minimum of 24 hours advance notice by the following means: a) Individualised notification using a method whereby there is a record of it having been sent to consumers shows supplies are carried out at voltages higher than 1 kV and to those establishments rendering services that are declared to be essential services, b) Advertising posters in visible spots with regard to all other consumers and by means of 2 of the most widely circulated printed media in the province.
Sweden	Interruptions for which the grid user has to be informed in advance.	Customers have not been warned in advance.	General requirements in the electricity act.
Switzerland	An interruption notified in advance to all affected customers with adequate notice.	An interruption not notified in advance to all affected customers or notified with inadequate notice.	Customers must be informed at least 24 hours in advance.

2.4.3. Voltage levels monitored

It would be very difficult to discuss the monitoring of interruptions on different voltage levels without first addressing how those voltage levels are defined. Since the terms low voltage (LV), medium voltage (MV), high voltage (HV) and extra high voltage (EHV) have quite different meanings across Europe, Table 2.3 should be consulted when referencing a specific voltage level.

Sometimes, the actual voltage level is not strictly defined or is different from its definition. In Bulgaria, the upper limit for medium voltage is defined as 75 kV while in reality the medium voltage only goes up to 35 kV. Certain voltages in Ireland are only defined nominally but their real value varies according to operating conditions. Some levels can correspond to both transmission and distribution as is the case in Belgium where grids with voltages between 30 and 36 kV are usually considered high voltage with local transmission function. Recently, however, DSOs in Belgium were allowed to build grids with voltages between 30 and 36 kV that have a distribution function. These grids are mainly developed to directly connect local generation units that are too big to the existing distribution grid.

TABLE 2.3 DEFINITIONS OF VOLTAGE LEVELS

Country	LV Network		MV Network		HV Network		EHV Network		Transmission	
	Min kV	Max kV	Min kV	Max kV	Min kV	Max kV	Min kV	Max kV	Min kV	Max kV
Austria		1	>1	36	>36	<220	220	380	110	380
Belgium	0,23	1	1	30-36 (7)	30-36 (7)	150	220	380	30	380
Bulgaria		1	1	35 (6)	110	400			110	400
Croatia	0,4	0,4	10	35	110	110	220	400	110	400
Czech Republic	0,4	0,6	6	35	110	110	220	400	110	400
Denmark	0,4	1	≥1	25	≥25	<100 (9)	100	400	100	400
Estonia	0,4	0,4	6	35	110	110	220	330	110	330
Finland	0,4	1	1	70	70	110	220	400	110	400
France		1	1	45	63	150	225	400	63	400
Germany		1	1	72,5	72,5	125	125	380	72,5	380
Great Britain		<1			1	<22	22	<132	132 (1)	400
Greece	0,4	0,4	6,6	22	66	150	400	400	66,4	400
Hungary	0,23	0,4	10	35	120	120	220	750		
Ireland	0,23	0,4	10 (2)	22,1	38 (3)	110	220	400	110	440
Italy		1	>1	35	>35	150	>150			
Latvia	0,22	0,4	6	20	110	110	330	330	110	330
Lithuania		0,4	6	35	110	330			110	330 (4)
Luxembourg	0,4	1	1	36	36	150	150	220	220	220
Malta		1	>1	33	35				(5)	(5)
The Netherlands		1	>1	36	>36	150	>150 (8)	380	110	380
Norway	0,23	1	1	22	36	132	220	420	132	420
Poland	0,23	0,4	1	60	110	110	220	750	110	750
Portugal		<1	1	<45	45	<110	110		132	400
Romania	0,4	1	1	20	110	110	220	750	220	750
Slovak Republic		1	Not defined	Not defined	1	110	110			
Slovenia	0,4	0,4	10	35	110	110	220	400	110	400
Spain	0	1	1	36	36	132	132	400	220	400
Sweden	0,4	1	1	36	36	150	220	400	220	400
Switzerland	0,22	1	1	36	36	220	220	380	220	380

(1) In England and Wales, transmission starts at 133 kV and goes up to 400 kV (lines are at 275 kV and 400 kV) In Scotland it includes the 132 kV lines.
(2) Variable according to operating conditions (nominal 10 kV).
(3) Variable according to operating conditions (nominal 38 kV).
(4) Starting in 2016, transmission lines will go up to 400 kV.
(5) No transmission system.
(6) The official definition of MV is up to 75 kV, but in practice the voltage only goes up to 35 kV.
(7) Grids with voltages between 30 and 36 kV.
(8) EHV levels are 220 and 380 kV.
(9) Before 2012 HV only went up to 70 kV.

Not all countries monitor interruptions that originate at all voltage levels, but all generate statistics for incidents at more than one voltage level as presented in Table 2.4. Interruptions originating on medium voltage (MV) level are monitored in all countries.

Incidents originating in transmission network, the definitions of which are shown in Table 2.3, are monitored in all countries except Latvia, Malta (which has no transmission system) and Romania.

TABLE 2.4 MONITORING OF VOLTAGE LEVELS WHERE INTERRUPTION ORIGINATED

Country	LV	MV	HV	EHV
Austria	X	X	X	X
Belgium		X	X	X
Bulgaria	X	X	X	X
Croatia	X	X	X	X
Cyprus	X	X	X	X
Czech Republic	X	X	X	X
Denmark	X	X	X	
Estonia		X	X	
Finland		X	X	X
France	X	X	X	X
Germany	X	X	X	X
Great Britain	X	X	X	X
Greece	X	X	X	X
Hungary	X	X	X	X
Ireland	X	X	X	
Italy	X	X	X	X
Latvia	X	X		
Lithuania	X	X	X	
Luxembourg	X	X	X	X
Malta		X	X	
The Netherlands	X	X	X	X
Norway	X	X	X	X
Poland	X	X	X	X
Portugal	X	X	X	X
Romania	X	X	X	
Slovak Republic	X	X	X	X
Slovenia		X	X	X
Spain	X	X	X	X
Sweden	X	X	X	X
Switzerland	X	X	X	X

Notes:
Portugal: LV, MV and HV levels include interruptions originated in upstream voltage levels. Interruptions are reported on a quarterly basis on all voltage levels and are reported separately for planned and unplanned interruptions, classified according with a set of causes established by the Quality of Service Code.

A presentation of voltage levels for which planned and unplanned long interruptions are monitored can be found in Table 2.5. In most cases, long interruptions are monitored on almost all voltage levels.

TABLE 2.5 VOLTAGE LEVELS FOR WHICH LONG INTERRUPTIONS ARE MONITORED

Country	Long planned interruptions voltage levels	Long unplanned interruptions voltage levels
Austria	Occurrence: all voltage levels. Customers: all voltage levels.	Occurrence: all voltage levels. Customers: all voltage levels.
Bulgaria	The data is available for MV and HV depending on the type of the 2 networks to which the customers are connected.	The data is available for MV and HV depending on the type of the 2 networks to which the customers are connected.
Croatia	HV, MV, LV	HV, MV, LV
Cyprus	HV, MV, LV	HV, MV, LV
Czech Republic	All voltage levels.	All voltage levels.
Denmark	HV, MV, LV	HV, MV, LV
Estonia	HV, MV, LV	HV, MV, LV
Finland	1-70 kV, 110 kV, 220 kV and 400 kV	1-70 kV, 110 kV, 220 kV and 400 kV
France	Customers connected to distribution networks only (MV + LV).	Available for all voltage levels, separately for each voltage level with respect to where the customer is connected.
Germany	All voltage levels.	All voltage levels.
Great Britain	All voltage levels.	All voltage levels.
Greece	MV and LV with respect to where the incident occurs.	MV and LV with respect to where the incident occurs.
Hungary	It applies to LV, MV and HV customers with respect to where the incident occurs.	It applies to all of the LV, MV, HV customers.
Ireland	Duration and number of interruptions per customer are reported to the NRA on an average (but not specific customer) basis. The information provided to the NRA for CIs and CMLs shows numbers affected with respect to where (defined by HV, MV and LV) the incident occurs. CI information shown by voltage level at which the customer was connected is also available.	Duration and number of interruptions per customer are reported to the NRA on an average (but not specific customers) basis. The information provided to the NRA for CIs and CMLs shows numbers affected with respect to where (defined by HV, MV and LV) the incident occurs. CI information shown by voltage level at which the customer was connected is also available.
Italy	All voltage levels.	All voltage levels.
Latvia	HV, MV, LV	HV, MV, LV
Luxembourg	HV, MV	HV, MV
Malta	Frequency and duration indicators of all planned interruption at 11kV substation level. Only duration data is gathered at LV and no indicators are available.	Frequency and duration indicators of all unplanned interruption at 11kV substation level. Only duration data is gathered at LV and no indicators are available.
The Netherlands	Planned interruptions are recorded at all voltage levels, but in practice only occur in the LV and MV networks. The data that is reported to the NRA makes a distinction between the voltage levels that the customers are connected to (at an aggregated level: LV, MV, HV and EHV). The NRA has no information about the location where the planned interruption takes place.	This applies to all voltage levels. The NRA only receives information concerning the voltage level that the customers are connected to. The NRA has no information regarding the location of origin of the unplanned interruption.
Norway	With respect to where the incident occurs: All voltage levels. With respect to where the customers are connected: All network IDs (1)	With respect to where the incident occurs: All voltage levels. With respect to where the customers are connected: All network IDs (1)
Poland	All voltage levels of transmission or distribution systems.	All voltage levels of transmission or distribution systems.
Portugal	All voltage levels, all customers, transmission, distribution. In practice, in transmission there is no long planned interruption. All planned interventions are done without customers' interruption.	All voltage levels, all customers, transmission, distribution.
Romania	HV, MV, LV with respect to where the customers are connected.	HV, MV, LV with respect to where the customers are connected.
Slovak Republic		TSO 220 and 400 kV, DSO HV>1 kV, LV<1 kV
Slovenia	Transmission networks: aggregated values for EHV and HV. Distribution networks: MV level (per MV substation feeder, calculated on different levels (MV feeder, distribution area, DSO). Aggregation on the distribution area (DSO) is also performed).	Transmission networks: aggregated values for EHV and HV. Distribution networks: MV level (per MV substation feeder, calculated on different levels (MV feeder, distribution area, DSO). Aggregation on the distribution area (DSO) is also performed).
Spain	All voltage levels. For interruptions at voltage levels over 1 kV, they are assigned to customers directly connected with the network. For low voltage customers (below 1 kV) the MV/LV transformer is used as the main criteria to assign incidents because the MV/LV transformers supply energy to all connected low voltage customers.	All voltage levels. For interruptions at voltage levels over 1 kV, they are assigned to customers directly connected with the network. For low voltage customers (below 1 kV) the MV/LV transformer is used as the main criteria to assign incidents because the MV/LV transformers supply energy to all connected low voltage customers.
Sweden	At all voltage levels and with respect to where the customer is connected.	At all voltage levels and with respect to where the customer is connected.
Switzerland	All voltage levels.	All voltage levels.

(1) Network ID#1: Central grid, i.e. the transmission network (HV and EHV).
Network ID#2: Regional grid, distribution network, masked configuration.
Network ID#3: Distribution grid (MV), radial configuration, more than 90% overhead lines.
Network ID#4: Distribution grid (MV), radial configuration, mixed overhead lines and cables.
Network ID#5: Distribution grid (MV), radial configuration, more than 90% cables.
Network ID#6: Distribution grid (LV), radial configuration.

2.4.4. Level of detail in indicators

Continuity of supply indicators are often captured for different categories, areas and voltage levels even within a single country. The following 2 tables (Table 2.6 and Table 2.7) provide an overview of the level of detail for which indicators are calculated and collected.

Further details, especially on monitoring the causes of interruptions, can be found in extensive footnotes.

TABLE 2.6 LEVEL OF DETAIL IN INDICATORS (1)

Country	National	System Operators	Region	Customer
Austria	X	X		
Belgium		X		X (1)
Bulgaria	X			X (2)
Croatia	X (13)	X	X (14)	
Cyprus			X (3)	
Czech Republic	X	X		
Denmark				X (4)
Estonia				X (5)
Finland		X	X (6)	
France		X		X
Germany	X	X		
Great Britain		X		X
Greece		X		
Hungary	X	X		X
Ireland	X	X (7)		
Italy		X (15)	X (15)	X (15)
Latvia		X		
Lithuania		X		X
Luxembourg		X		
Malta		X (8)		
The Netherlands	X	X		
Norway	X	X	X	X
Poland	X	X		
Portugal	X (9)	X	X (9)	X
Romania		X		
Slovak Republic	X	X		
Slovenia	X	X	X (10)	X (11)
Spain		X	X (12)	X
Sweden	X	X	X	X
Switzerland	X	X	X	

(1) EHV/HV : direct customer of TSO.
(2) At single customer level, distribution and transmission customers.
(3) Monitored at district level.
(4) All kinds of customers at aggregated and single-customer level.
(5) For all customers at single-customer level.
(6) In each network operator's geographical area of responsibility.
(7) The DSO and TSO may have further breakdowns, but the NRA does not get involved in this detail.
(8) Continuity indicators are calculated at 11 kV substation level.
(9) Only distribution is monitored at national, district and municipality level.
(10) Distribution monitored per distribution area.
(11) Monitoring on the single customer level is limited to the customers that are subject of the compensation scheme.
(12) Municipality.
(13) Transmission level only.
(14) Distribution level only.
(15) At distribution level, data are collected for "districts" (around 300 areas all over the Country) and aggregated per DSO and for the whole nation; at transmission level, data are collected at System operator level. Data per single customer are collected for each MV customer (around 100,000 customers) and in case of very long interruptions.

TABLE 2.7 LEVEL OF DETAIL IN INDICATORS (2)

Country	Voltage level	Causes	Cable/aerial
Austria	Yes	Yes (1)	No
Belgium	Yes	Yes (2)	No
Bulgaria	Yes	Yes (3)	Yes
Croatia	Yes	Yes (4)	No
Cyprus	Yes	Yes (5)	Yes
Czech Republic	Yes	Yes (6)	No
Denmark	Yes	Yes	No
Estonia	Yes	Yes (7)	No
Finland	Yes	No (8)	No
France	Yes	Yes (9)	Yes
Germany	Yes	Yes (10)	No
Great Britain	Yes	Yes (11)	Yes
Greece	Yes	Yes (12)	No
Hungary	Yes	Yes (13)	Yes
Ireland	Yes		
Italy	Yes	Yes (14)	No
Latvia	No	No	No
Lithuania	Yes	Yes (15)	Yes
Luxembourg	Yes	Yes (16)	No
Malta	Yes	Yes	Yes
The Netherlands	Yes	Yes (17)	No
Norway	Yes	Yes (18)	Yes
Poland	No	No	No
Portugal	Yes	Yes (19)	No
Romania	Yes	Yes (20)	No
Slovak Republic	Yes	No	No
Slovenia	Yes	Yes (21)	No
Spain	No	Yes (22)	Yes
Sweden	Yes (25)	Yes (23)	No
Switzerland	Yes	Yes (24)	No

(1) Planned, unplanned (force majeure, third party interference, atmospheric, system operator internal, system perturbation from other network/generation).
(2) MV/LV: only at specific voltage.
EHV/HV: Material failure, human error TSO, human error third party, human error DSO, weather, system response (interruption caused or aggravated by protection & automation system – whatever the cause), animal, fault outside grid, unknown.
(3) Planned, unplanned, third party interruptions and force majeure.
(4) Ca. 30 categories like bad maintenance, manipulation errors, technical causes, third party, force majeure, etc.
(5) Planned Interruptions (Expansion of network, maintenance, rectification of network after a fault.) Unplanned Interruptions (Operational reason, weather, related human error, equipment failure).
(6) Unplanned interruptions: Caused by failure of equipment of TSO or DSO, or during its operation, under standard weather conditions, under severe weather conditions, caused by third party interference, forced, extraordinary, caused by event outside the system.
(7) List of 60 different types of causes, 2 levels what and why happened.
(8) Recording: planned and unplanned interruptions in network operators own network.
(9) Atmospheric events (lightning, snow, wind), equipment failures (line, substation), vegetation contact, human operation cause, customer installation cause, third party cause, non-identified cause.
(10) 1. Atmospheric influence 2. Caused by third party 3. Responsibility of the network operator 4. Others (planned) 5. Feedback effects caused in other networks 6. Exchange of meter 7. Force majeure.
(11) For each recorded incident the DNOs have to record a cause code as the reason for the incident. So if there was an incident due to a branch hitting a line and causing an interruption for customers, the DNO would put the cause code in the reporting template against this incident. For the list of causes please refer to the 5th Benchmarking Report.
(12) Unplanned interruptions: 1. External (due to transmission system infeed loss, fires, floods etc.), 2. Due to exceptional weather conditions, 3. Other. Planned interruptions: 1. System development works, 2. Maintenance works, 3. Repair work.
(13) The classification of causes is made by the DSOs.
(14) For transmission, there are 4 macro-categories: lack of system adequacy, force majeure, external causes (i.e. users), TSO causes. For distribution, there are 3 macro-categories: force majeure, external causes (i.e. users), DSO causes. For transmission, there is a 2nd level classification (about 15 causes) and 3rd level classification (about 50 causes). For distribution, a 2nd level classification has been entered into force in 2012 (about 20 causes).
(15) 1. Force majeure; 2. External causes; 3. Causes attributable to system operator responsibility; 4. Non – identified causes.
(16) Atmospheric, force majeure, damage inflicted by third party internal to network, upstream network, downstream network.

(17) Manufacturer, network design, assembly, operation, aging/wear, external influence (e.g. excavation works), soil movement, moisture, weather, operational stress, internal defect, unknown.
(18) Main categories: 1. surroundings, 2. people (staff), 3. people (others), 4. operational stress, 5. technical equipment, 6. design/installation, 7. others, 8. cause unknown. These main categories are further divided into subcategories. In audits NVE emphasises the importance of trying to avoid using the category "cause unknown".
(19) Planned interruptions: for reasons of public interest, service reasons and other networks or installations.
Unplanned interruptions: (i) Exceptional events: security reasons, strikes, extreme natural conditions, odd objects in the network, fire or flood, vandalism, third party; (ii) Non-exceptional events: security reasons, strikes, extreme natural conditions, odd objects in the network, fire or flood, vandalism, third party, atmospheric conditions, maintenance, network protections, electric equipment, technical reasons, human intervention, unknown reasons, other networks or installations.
(20) a. planned; b. unplanned due to force majeure; c. unplanned due to customers; d. unplanned excluding b and c.
(21) Unplanned interruptions: 1) responsibility of system operator (DSO/TSO) 2) third party and 3) force majeure. Planned interruptions: no cause categories are applied. All interruptions must be classified into one of the categories. Unidentified causes are attributed to the DSO/TSO (responsibility of DSO/TSO). We do not categorise the cause of short interruptions.
(22) For planned interruptions: transmission and distribution. For unplanned interruptions: Third party, generation, transmission, force majeure, distribution.
(23) The DSOs decide which categories to use.
(24) Planned interruptions, unplanned interruptions (caused by other DSO, natural phenomena, human behaviour, operational cause, external cause, other cause).
(25) Indicators are presented at some voltage levels: at low voltage and high voltage (in this case high voltage means >1,000 V).

2.4.5. Measurement techniques

Roughly half of the countries use automatic logging or automatic identifications when measuring long and short interruptions (Table 2.8). About a third of the countries use both.

TABLE 2.8 MEASUREMENT TECHNIQUES FOR LONG AND SHORT INTERRUPTIONS

Country	Identification of affected network users	Automatic identification	Automatic logging
Austria	No common rules or standardised way of identifying the customers affected. The way of estimating differs from network operator to network operator.	No	No
Belgium	For EHV/HV: All the connection points of the EHV/HV grids are identified individually. These points are either connection point of individual HV-customers or connection points of distribution grids.	No	No
Bulgaria	There is no automatic identification of affected customers.	No	No
Croatia	1. Customers are allocated by substations; 2. Number of affected customers is estimated by application for network system reports (DISPO).	Yes	Yes
Cyprus	Yes there is a rule for estimating the customers affected. (Assumption is 1 customer for every 2 kVA).	Yes	No
Czech Republic	At MV and HV by SCADA system. At LV by technical scheme of the network.		No
Denmark	No common rules or standardised way of identifying the customers affected.	No	No
Estonia	Automatic identification of customers affected for interruptions on MV level, on basis of messages from customers on LV level via GIS.	Yes	Yes
Finland	Customers are identified by being sorted in different voltage levels.	No	No
France	On the transmission network, each customer's substation feeding is individually monitored. On both transmission and distribution system, network system and commercial system are connected.	Yes	Yes
Germany	There is no standardised way of identifying the affected customers. The way of estimating differs from one network operator to another.	No	No
Great Britain	Ofgem collects data at a system level for each of the 14 licensed electricity distribution businesses. Ofgem also collects disaggregated data for each MV circuit so that comparisons can be made across the distribution businesses.	Yes	Yes
Greece	For interruptions originating at MV, the number of customers affected is estimated through the interrupted MV/LV transformer installed power. For interruptions originating at LV, the number of customers affected is estimated through the rated current of the interrupted LV line fuse.	Yes	No
Hungary	At present it is allowed to estimate the number of customers affected. The NRA has already issued a resolution on determination of the number of customers affected, which will lay down the rules for estimation. The implementation of the resolution is still in progress.	No	No

Country	Identification of affected network users	Automatic identification	Automatic logging
Ireland	This level of detail is not specified by the NRA.		
Italy	For transmission, the sources of data/info include: the remote control system, the SCADA, the log of the remote control system, other recording systems, registrations by EHV-HV users, registrations by the distribution network operators. For distribution: the remote control system or other systems (SCADA for the MV network); various options are allowed for recording LV customers affected (the simplest refer to average number of customers, the most complex involves the single LV smart meters).	Yes	Yes
Latvia	The DSO can identify users affected by interruptions by using SCADA system and Geographic Information System data (GIS).	No	No
Lithuania	Automatically and manually.	Yes	
Luxembourg	HV, MV: details in DSOs system. LV: currently average number per transformer.	Yes	Yes
Malta	Until 2015 it was assumed that the number of customers supplied from a substation that experienced an outage was proportional to the rating (in kVA) of the substation transformer. From 2016 onwards, the number of customers fed from each MV/LV substation is stored in the outage reporting system that is used to record the interruption of supply to these MV/LV substations. SAIDI and CAIDI for outages on the MV network will now be based on the actual number of customers affected.	No	No
The Netherlands	Identification of affected customers mostly occurs through well-established and documented methods of estimation, which are part of a national system for the registration of interruptions.	Yes	Yes
Norway	The standardised system for reporting of interruption data (FASIT) uses data from the Customer Information System regarding exactly how many customers are connected to each of the distribution transformers affected by an interruption. The customers are divided into 36 different end-user groups, and 2 sub-groups, and the interruptions are monitored for all the 36+2 end-user groups (The 36+2 end-user groups are distributed on the 6 different customer categories), TSO/DSO network areas, counties and the country as a whole.	Yes	Yes
Poland	The customers at LV level are estimated, while at the higher levels they are all identified.	No	No
Portugal	For interruptions that affect EHV, HV and MV, TSO and DSO can identify users affected by interruptions by using SCADA system. For long interruptions with origin at LV, affected customers are identified based on phone calls.	Yes, for EHV, HV and MV through SCADA system.	No
Romania	An automatic system of calculation is in progress, until end of 2012, in order to record the interruptions for the customers of HV and MV level.		Yes
Slovak Republic	It is in competence of operator DSO and TSO.		
Slovenia	Identification is performed by the automatic binding of the number of affected customers through the entity properties in SCADA (i.e. substation, feeder properties etc.). This applies on the EHV, HV and MV levels. For LV (not yet covered) either the call-centres or AMI (Smart Grids) services will be used. Exemptions: some cases have been identified where the meta data in SCADA is not complete or not up-to-date. In such cases, operator performs manual mapping in post-processing phase (applying the data from external source).	No	Yes
Spain	Each customer is associated to a transformation centre or element in the distribution network. Each interruption in this element is associated with the customer.		Yes
Sweden	By a unique ID for each customer.	Yes (for >90% of network users) (1)	Yes (for >90% of network users) (1)
Switzerland	No common rules or standardised way of identifying the customers affected.	No	No

(1) Yes, for more than 90% of customers when the origin of the interruption is at medium voltage level; 100% of customers if the origin of the interruption is at high and extra high voltage. If the origin of interruption is at low voltage level, it is difficult to assess how many DSOs have automatic identification/logging of interruptions. Because interruptions at low voltage affect few customers, automatic identification and automatic logging is considered to be implemented for >90% of network users.

2.5. CONTINUITY OF SUPPLY INDICATORS

Different types of indicators or same indicators with different weighting methods present an obstacle to the main goal of this section, which is comparison of national continuity data across Europe. Moreover, while all countries keep track of their long interruptions, short interruptions are monitored in less than half of the countries. While Section 2.6 will analyse the values of national data, this section will examine the types of indicators used for long and short interruptions.

2.5.1. Long interruptions

Indicators used across Europe to quantify the number and duration of long interruptions are listed in Table 2.9. The definitions of these are given in the 4th Benchmarking Report for distribution and transmission systems. Please see the list of abbreviations for the meaning of individual indicators. The table also gives information on the weighting method used. SAIDI and SAIFI are commonly used whereas the weighting is regularly based on the number of network users. ENS and AIT (Average Interruption Time) are mostly used for transmission networks.

TABLE 2.9 INDICATORS FOR LONG INTERRUPTIONS

Country	Index	Weighting
Austria	SAIDI, SAIFI, ASIDI, ASIFI, CAIDI, (CML, ENS).	Weighted by both the transformer stations affected and by the number of customers.
Belgium	SAIDI, AIT.	SAIDI used for LV/MV and weighted by the number of customers. AIT used for HV/EHV and weighted by the power affected.
Bulgaria	SAIDI, SAIFI.	By the number of customers.
Croatia	SAIDI, SAIFI.	
Cyprus	SAIDI, SAIFI, per cause, per voltage, percentage indicators, lost MVA's per cause, affected consumers, faults per type, faults per location, faults per substation/ feeder, Average Time to restore supply, Time interval to restore of supply.	By the power affected.
Czech Republic	Distribution: SAIFI, SAIDI, CAIDI. Transmission: ENS, AID (sum of duration divided by number of interruptions).	Distribution: by the number of customers. Transmission: not weighted.
Denmark	SAIDI, SAIFI.	It is weighted by type of interruption, kilometres of electricity network and by the number of customers.
Estonia	SAIFI, CAIDI, total annual interruption time for each customer.	By the number of customers.
Finland	DSOs: 1-70 kV: T-SAIDI and T-SAIFI, < 1 kV: amount of interruptions; and 110 kV: amount and duration of interruptions (in total). TSO and high voltage network operators: In 400 kV, 220 kV and 110 kV: duration of interruptions and amount of interruptions (in total).	By the annual energy consumption.
France	AIT, SAIFI and ENS for transmission network, as defined SAIFI, SAIDI and "Percentage of customers with insufficient quality of supply" for distribution network. There are several versions of each of these indicators, depending on the type of disconnection (planned/ unplanned), the voltage level, and the cause (exceptional event included or not).	Depends on the indicator. For continuity indicators such as SAIDI, it is weighted by the number of delivery points affected (for HV and EHV) and by the number of customers (for LV).
Germany	SAIDI (LV), ASIDI (MV), SAIFI.	LV: Number of customers. MV: rated apparent power of the affected power.
Great Britain	The 2 main indicators are Customer Interruptions and Customer Minutes Lost. Ofgem also collects information on the number of transmission incidents and the level of energy not supplied for each incident.	By the number of customers.
Greece	SAIDI, SAIFI.	By the number of customers.
Hungary	Distribution level: the indicators used in IEEE Std. 1366-2003: SAIDI, SAIFI, CAIDI for both planned and unplanned interruptions. Transmission level: AIT (Average Interruption Time) – ENS/ES (Outage rate) is used at both distribution and transmission level.	By the number of customers.

Country	Index	Weighting
Ireland	Customer minutes lost, customer interruptions.	For distribution, the CIs and CMLs are reported on an average customer basis. For transmission, the system minutes lost indicator is related to the power affected.
Italy	Transmission: ENS (energy not supplied), ENW (energy not withdrawn), AIT (average interruption time), SAIFI. Distribution: SAIDI, SAIFI, number of customers affected by interruptions longer than 8 hours.	For distribution: by the number of users affected. For transmission: number indicators are referred to transmission users.
Latvia	SAIDI, SAIFI, CAIDI, ENS.	By the number of customers.
Lithuania	TSO: ENS, AIT. DSO: SAIDI, SAIFI.	By the number of customers. ENS, AIT – interrupted power.
Luxembourg	SAIDI, SAIFI.	By the number of customers.
Malta	SAIDI and CAIDI for each interruption but not classified as long, short and transient.	Indicators are calculated at MV level and interruptions are weighted by transformer kVA installed at MV level.
The Netherlands	SAIDI, SAIFI and CAIDI.	By the number of customers.
Norway	With reference to end-users (all voltage levels): SAIDI, SAIFI, CAIDI, CTAIDI, CAIFI, interrupted power per incident and energy not supplied (ENS). With reference to reporting points (i.e. distribution transformer or a customer connected above 1 kV): number and durations.	By the number of customers. By the amount of ENS and by the amount of interrupted power.
Poland	Distribution level according to the IEEE Std. 1366-2003: SAIDI, SAIFI. Transmission level: ENS, AIT and according to the IEEE Std. 1366-2003 SAIDI, SAIFI.	By the number of customers.
Portugal	Transmission: ENS, AIT, SAIFI, SAIDI, SARI. Distribution: SAIFI HV, SAIDI HV, END MV, AIT MV (TIEPI), SAIFI MV, SAIFI LV, SAIDI MV, SAIDI LV	SAIFI and SAIDI: weighted by delivered points (transmission, HV and MV) and by the number of customers (LV); TIE (Distribution – TIEPI) and END (distribution): weighted by installed power; ENS (transmission): estimated; TIE (transmission): energy not supplied and energy supplied.
Romania	DSO: SAIFI, SAIDI; ENS and AIT at 110 kV level. TSO: ENS and AIT for the whole country.	By the number of customers. At 110 kV (max distribution level) and TSO (220-750 kV), ENS and AIT are used; at 110 kV SAIFI and SAIDI are also used.
Slovak Republic	1. N 400 (average number of unplanned interruptions relating to the one transformer on the voltage level 400 kV). 2. N 220 (average number of unplanned interruptions relating to the one transformer on the voltage level 220 kV).	By the number of customers. By the number of transformers (TSO).
Slovenia	Distribution: SAIDI, SAIFI, CAIDI, CAIFI. Transmission: SAIDI, SAIFI (implicitly ENS, AIT, AIF, AID).	By the number of customers.
Spain	In distribution TIEPI, NIEPI, 80 Percentile of TIEPI and 80 Percentile of NIEPI at zonal level or individual level. In transmission: ENS, AIT and facility available percentage.	By the power affected.
Sweden	Since data on customer level is available regarding interruptions, NIS-tagged information, transferred energy, max effect and transferred energy of the overlying transformer, a large range of customer level and system level indicators can be calculated such as active power not supplied in kW, energy not supplied, ASIDI, ASIFI, SAIDI, SAIFI, customer experiencing multiple interruptions (CEMI), confidence interval reflecting best and worst served customers at arbitrary level, number of customer experiencing different yearly aggregated duration of interruption etc.	By the number of customers.
Switzerland	Distribution: SAIDI, SAIFI. Transmission: SAIDI, SAIFI, ENS.	By the number of customers.

2.5.2. Short and transient interruptions

Short and transient interruptions are not monitored as widely as the long ones. Less than half of the responding countries collect separate data on short or transient interruptions. These are Austria, Cyprus, the Czech Republic, Finland, France, Hungary, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Slovenia and Sweden. Information on the indicators for short and transient interruptions used across Europe is summarised in Table 2.10. The number of short interruptions per year is used in almost every country listed in this table. Some give separate indicators for short and transient interruptions; some have one indicator covering both, while others exclude transient interruptions from monitoring altogether. Again, definitions of the indicators are given in the 4th Benchmarking Report.

TABLE 2.10 INDICATORS FOR SHORT AND TRANSIENT INTERRUPTIONS IN COUNTRIES THAT MONITOR THEM

Country	Short	Transient
Austria	MAIFI (DSO) (1).	None
Cyprus	SAIDI, SAIFI, per cause, per voltage, percentage indicators, lost MVA's per cause, affected consumers, faults per type, faults per location, faults per substation/ feeder, Average Time for restoration of supply, Time interval for restoration of supply.	None
Czech Republic	No specific indicator. Distribution system operators monitor them at the chosen points according the technical report CENELEC TR 50555.	No specific indicator. Distribution system operators monitor them at the chosen points according the technical report CENELEC TR 50555.
Finland	In MV amount of short interruptions (high speed automatic reclosing and delayed automatic reclosing) which are proportional to the annual amount of energy.	
France	MAIFI for transmission network, MAIFI and percentage of customers with "insufficient quality of supply" for distribution network.	None
Hungary	Distribution level: indicators used in IEEE Std. 1366-2003: MAIFI (for MV networks). Transmission level: no indicator.	Distribution level: indicators used in IEEE Std. 1366-2003: MAIFI (for MV networks). Transmission level: no indicator.
Italy	For transmission: ENS (energy not supplied), ENW (energy not withdrawn), AIT (average interruption time), MAIFI. For distribution: MAIFI, separately for short and transient interruptions.	For transmission: number of transient interruptions. For distribution: number of transient interruptions.
Latvia	MAIFI	
Lithuania	MAIFI (DSO)	
Norway	With reference to end-users (all voltage levels): SAIDI, SAIFI, CAIDI, CTAIDI, CAIFI, interrupted power per incident and energy not supplied (ENS). With reference to reporting points (i.e. distribution transformer or a customer connected above 1 kV): number and durations.	Included in short interruptions.
Poland	Distribution level according to the IEEE Std. 1366-2003: MAIFI. Transmission level: no indicator.	
Portugal	MAIFI (EHV, HV and MV).	None
Slovenia	Distribution and transmission: MAIFI. Distribution: MAIFI-E.	
Sweden	MAIFI-E.	

(1) Published on DSO level.

2.5.3. Discussion of indicators

From the tables presented, it is clear that a wide range of indicators is implemented across Europe. The use of multiple indicators to quantify the continuity of supply has resulted in a greater availability of information and possibilities to observe trends.

SAIDI and SAIFI are the basic indicators reported in almost all countries, albeit under different names and with different methods for weighting the interruptions.

The method of weighting impacts the results and leads to different biases towards different types of network users. When weighting is based on the number of network users, users are treated equally regardless of their size and consumption levels.

When weighting is based on interrupted power or energy not supplied (ENS), an interruption gets a higher weighting whenever the total interrupted power is higher. This might happen when network users with larger demand are interrupted or when the interruption takes place during a period of higher consumption. Weighting based on contracted power, rated power or annual power consumption makes the contribution of an incident during high load the same as in the case of an incident during low load.

Any weighting based on power and energy is biased towards network users with larger demand. As these users typically suffer fewer and shorter interruptions, this is expected to result in lower values for frequency and duration of interruptions than weighting based on number of network users.

It is important to remember that both SAIDI and SAIFI can be presented with or without exceptional events. In this report, more than two thirds of the countries have a definition of exceptional events, which mostly includes natural causes such as strong winds, snowstorms, floods and earthquakes. The individual definitions, however, are far from harmonised. Non-natural causes include among others, wars, sabotage, acts of terrorism and embargos.

Sometimes the assumptions are a simplification of the actual consequences of interruptions. A good example of this is ENS that gives the total amount of energy that would have been supplied to the interrupted customers if there would not have been any interruption [4]. The fact that there is no energy consumption during the interruption makes it impossible to exactly measure this indicator.

The indicators such as Customer Average Interruption Frequency Index (CAIFI) and Customer Total Average Interruption Duration Index (CTAIDI) give a better impression of the continuity of supply as experienced by those network users that are affected by at least one interruption. The differences in value between SAIFI and CAIFI, and between SAIDI and CTAIDI, give an impression of the spread in the number of interruptions between different network users. The distribution of number of interruptions experienced by each individual user gives this information in a more direct way, but results in more indicators, making comparisons and trend analysis more complicated. CTAIDI is currently only used by Norway, while CAIFI is used by both Norway and Slovenia. CEMI [10] [11], a similar indicator that measures percentage of customers experiencing more than one interruption, is used by Sweden.

2.6. ANALYSIS OF CONTINUITY BY NATIONAL DATA

European countries use different indicators and different weighting methods when evaluating interruptions. Two main groups of indicators – "*minutes lost per year*" [SAIDI, Customer Minutes Lost (CML), Average System Interruption Duration Index (ASIDI), Transformer System Average Interruption Duration Index (T-SAIDI) or "Equivalent interruption time related to the installed capacity" (TIEPI)] and "*number of interruptions per year*" [SAIFI, Customer interruptions (CI), Average System Interruption Frequency Index (ASIFI), Transformer System Average Interruption Frequency Index (T-SAIFI), or "Equivalent number of interruptions related to the installed capacity" (NIEPI)] – are collected by countries and partly presented in this chapter. Their values are compared over a number of years.

In addition to the monitoring of duration and frequency of interruptions, one can also examine whether the interruptions were planned or unplanned. For more information, please refer to Section 2.4.2 where the definitions of planned and unplanned interruptions are listed by country, as well as the rules issued on the notice to the affected network user for planned interruptions (minimum time-requested, procedures for giving notice, etc.). Which occurrences are considered as exceptional events can be determined in different ways. Some countries have a more statistical approach, while others focus their definition on the causes of exceptional events. More information on this topic can be found in the Annex A to Chapter "Electricity – Continuity of supply" on Continuity of Supply data.

When interpreting the results and especially when comparing between countries, one should consider the differences in calculation of the indices and in the voltage levels at which incidents are monitored. For example, Slovenia specified that while all voltage levels are monitored, only the MV data is used due to unavailability of LV data and a different weighting method for calculating SAIDI and SAIFI on the EHV/HV level; Finland reports T-SAIDI or Transformer SAIDI (SAIDI weighted by the annual energy consumption); Norway's data since 2014 includes also incidents at LV; and Malta calculates at 11 kV and includes interruptions on this level or upstream. Despite the difference in names and calculation methods between countries, the results are shown in the same diagrams.

It should also be noted that indicators representing the number of interruptions, for example SAIFI, are not always easily comparable among countries. The reason for this is that the aggregation rules for interruptions differ across Europe. In some countries, all interruptions occurring during a specific defined time period are considered as a single interruption.

The system indicators ("minutes lost per year" and "number of interruptions per year") for the different countries and years are compared in Figure 2.1 and Figure 2.3, which illustrate the overall indicators of planned and unplanned long interruptions. More specific indicators are addressed in subsequent sections. Since a wide spread of indicators makes the reading of the lower half of some graphs more difficult, certain figures such as Figure 2.2 and Figure 2.4 show only the countries where the worst values over the observed period (2002-2014) do not exceed the limit chosen in any of the observed years. This presentation has no effect on data and was only done for visibility reasons.

FIGURE 2.1 OVERALL PLANNED AND UNPLANNED LONG INTERRUPTIONS (MINUTES LOST PER YEAR)

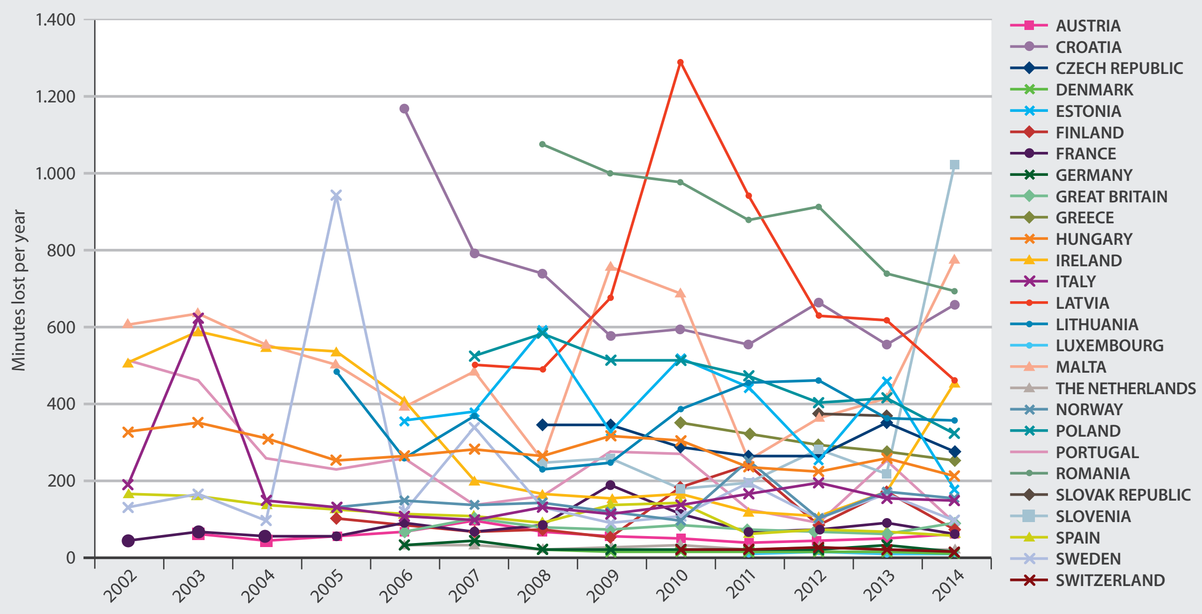
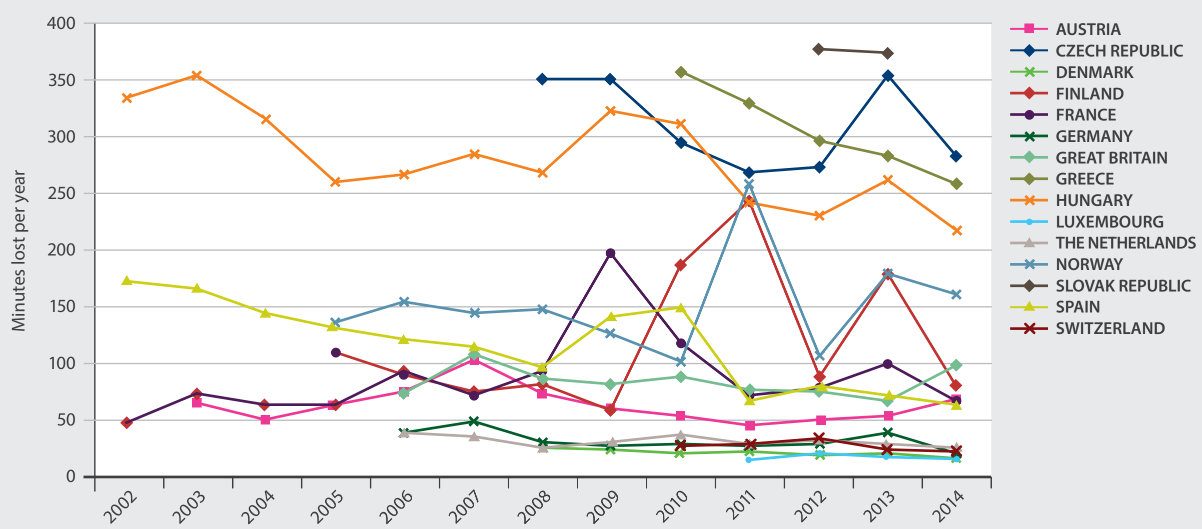


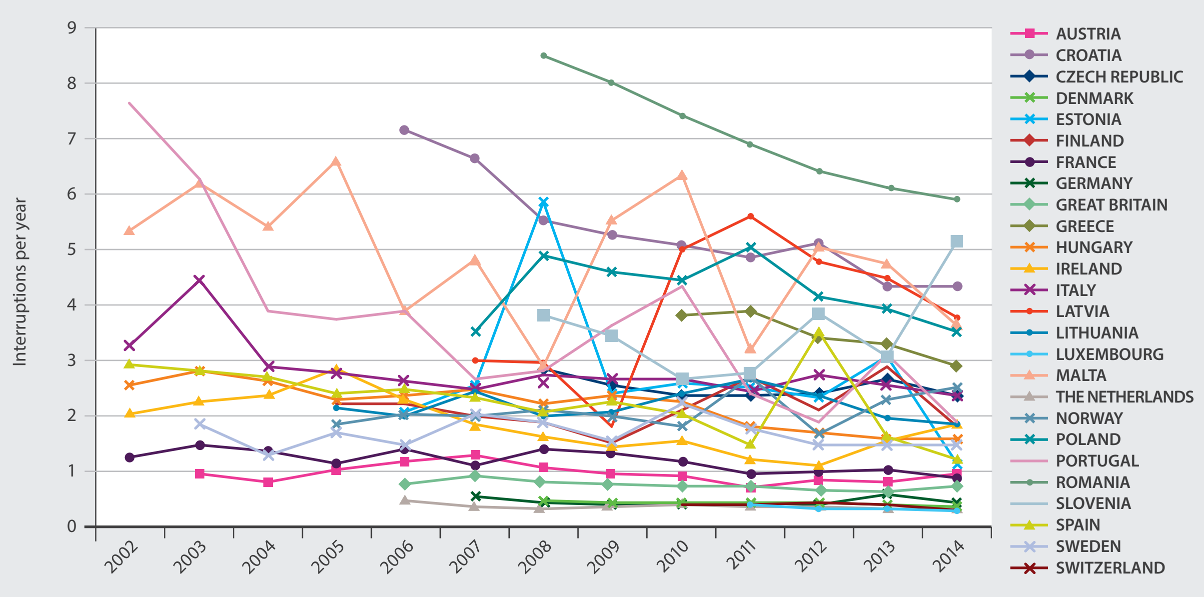
Figure 2.1 represents the overall planned and unplanned long interruptions as minutes lost per year and shows a very wide range of the indicators (15 -1,300 minutes). No trends are visible and values vary over time. The reason is that the overall indicators include all interruptions (planned and unplanned) as well as exceptional events.

FIGURE 2.2 OVERALL PLANNED AND UNPLANNED LONG INTERRUPTIONS (MINUTES LOST PER YEAR); ONLY COUNTRIES NOT EXCEEDING 400 MINUTES



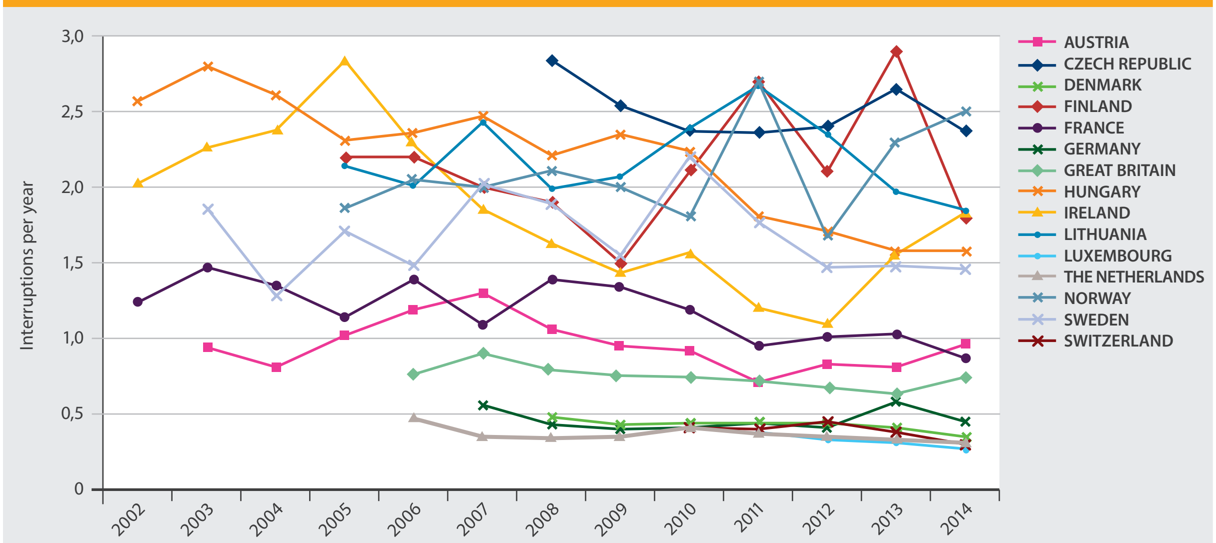
A better view of the countries with lower values of this indicator can be seen in Figure 2.2. This figure shows the same data as Figure 2.1, but the values are limited to 400 minutes lost per year with everything above (worse continuity values) excluded. In this case it is easier to observe the countries with very low indicators and relatively stable course which do not exceed 50 minutes lost per year (Denmark, Germany, Luxembourg, the Netherlands and Switzerland). These countries can also be characterised as those with high proportion of cable circuits at MV networks. Technical characteristics of electricity networks across Europe can be found in Section 2.6.6.

FIGURE 2.3 OVERALL PLANNED AND UNPLANNED LONG INTERRUPTIONS (NUMBER OF INTERRUPTIONS PER YEAR)



The overall planned and unplanned long interruptions as number of interruptions per year are shown in Figure 2.3. There is also a wide range and variability of the indicators, except for the countries with very low indicators mentioned above. It cannot be said that there is a trend in all the countries, but 5 show decreasing values (Croatia, Greece, Hungary Romania and Spain).

FIGURE 2.4 OVERALL PLANNED AND UNPLANNED LONG INTERRUPTIONS (NUMBER OF INTERRUPTIONS PER YEAR); ONLY COUNTRIES NOT EXCEEDING 3 INTERRUPTIONS

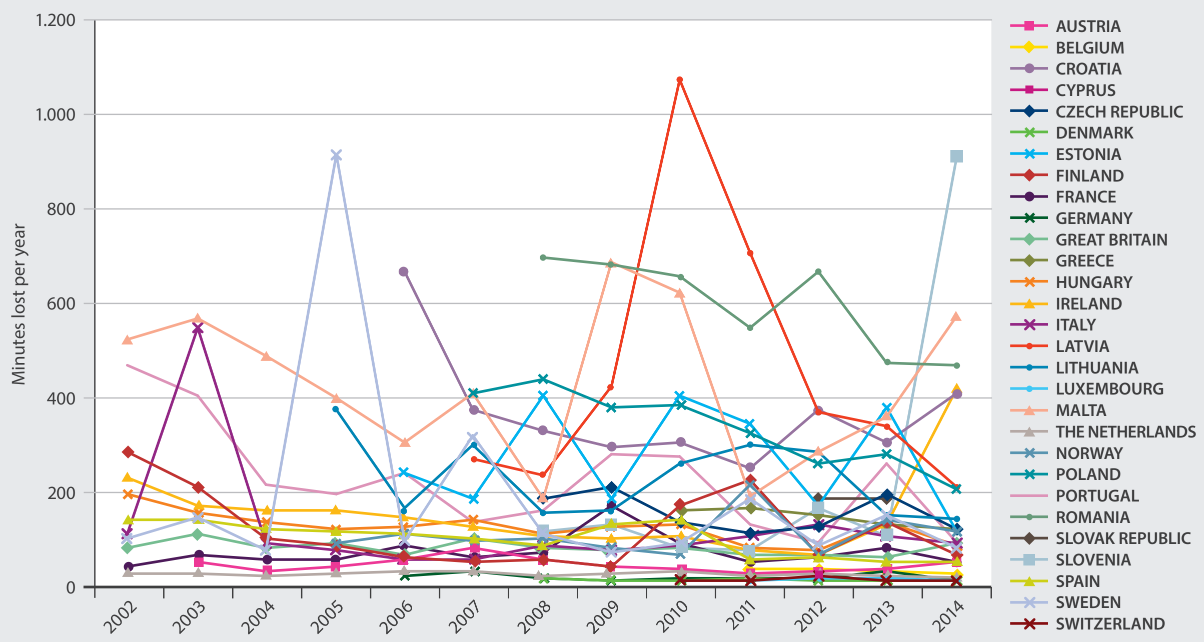


Again, a better view of countries with lower values of this indicator is in Figure 2.4, which shows only countries that do not exceed the limit of 3 interruptions per year during the observed period. Relatively stable numbers of interruptions (lower than 1 per year) are in Denmark, Germany, Great Britain, Luxembourg, the Netherlands and Switzerland.

2.6.1. Unplanned long interruptions, all events

Taking planned interruptions out, Figure 2.5 presents the minutes lost per year during unplanned long interruptions including all events. Due to extreme weather situations that have occurred in many European countries over recent years the values show a lot of variations. Therefore the clean values (without exceptional events) are presented in next section (Section 2.6.2). In general, the minutes lost over the 29 countries that contributed data, ranges between 10 and 1,100 minutes per year.

FIGURE 2.5 UNPLANNED LONG INTERRUPTIONS INCLUDING ALL EVENTS (MINUTES LOST PER YEAR)



Countries not exceeding 200 minutes lost per year are presented in Figure 2.6 and while there are countries with some minor reduction, the values still vary a lot. Apart from Romania and Poland from the figure above, the reduction in the recent years is also visible in Greece.

FIGURE 2.6 UNPLANNED LONG INTERRUPTIONS INCLUDING ALL EVENTS (MINUTES LOST PER YEAR); ONLY COUNTRIES NOT EXCEEDING 200 MINUTES

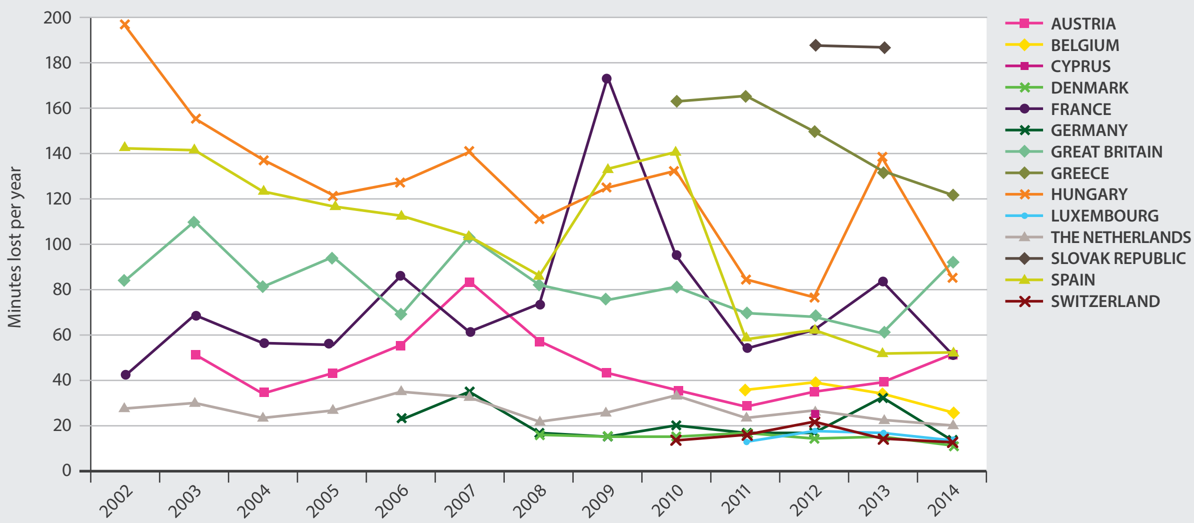
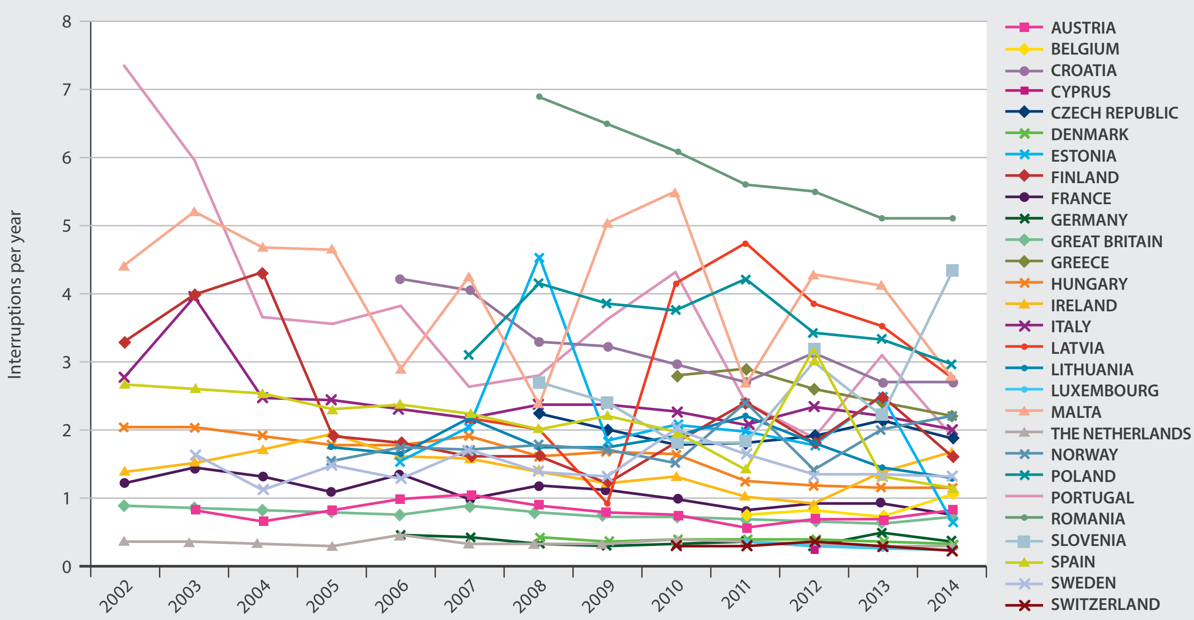


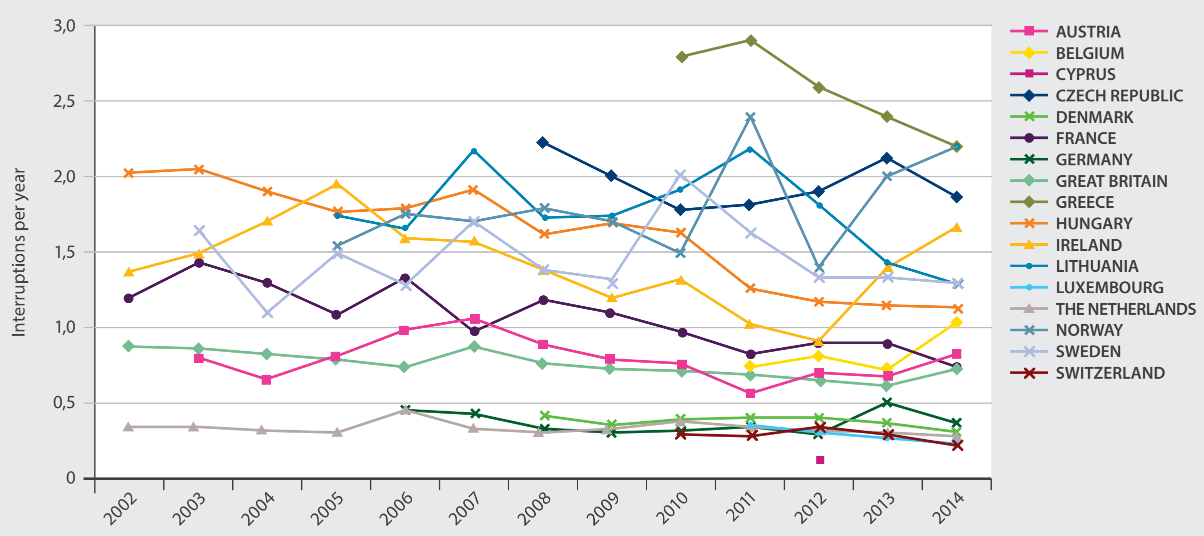
Figure 2.7 shows the number of interruptions per year, with unplanned long interruptions including all events. The year-to-year variation in the number of interruptions is less than the variation for the minutes lost. This is because extreme events (e.g. blackout) more often result in lower number of long interruptions than higher number of short interruptions. By way of example, the number of interruptions in 2003 in Italy is about one interruption higher than the value in preceding and subsequent years (because the blackout on 28 September 2003 affected almost all of Italy); however, the minutes lost are 450 minutes higher than in preceding and subsequent years.

FIGURE 2.7 UNPLANNED LONG INTERRUPTIONS INCLUDING ALL EVENTS (NUMBER OF INTERRUPTIONS)



By limiting the worst values of the number of unplanned long interruptions including all events to 3 interruptions per year, an improvement in Hungary, France and partly in Lithuania can be seen in Figure 2.8.

FIGURE 2.8 UNPLANNED LONG INTERRUPTIONS INCLUDING ALL EVENTS (NUMBER OF INTERRUPTIONS); ONLY COUNTRIES NOT EXCEEDING 3 INTERRUPTIONS



2.6.2. Unplanned long interruptions, excluding exceptional events

Data was also obtained for the continuity of supply indicators excluding exceptional events. When comparing the values without exceptional events between countries, significant care has to be taken as every country has its own methodology for determining what constitutes an exceptional event, which renders a direct comparison more difficult.

Figure 2.9 shows the minutes lost per year for unplanned interruptions, excluding exceptional events. The filtered values display less year-to-year variations than the values in Figure 2.7 where all interruptions are included. The countries are now roughly divided into 2 groups: one with relatively high and variable values (Bulgaria, Croatia, Malta, Poland and Romania); and another with relatively low and stable values, that are better visible in Figure 2.10. The curves in this figure show continuously decreasing trend in nearly all countries.

FIGURE 2.9 UNPLANNED LONG INTERRUPTIONS EXCLUDING EXCEPTIONAL EVENTS (MINUTES LOST PER YEAR)

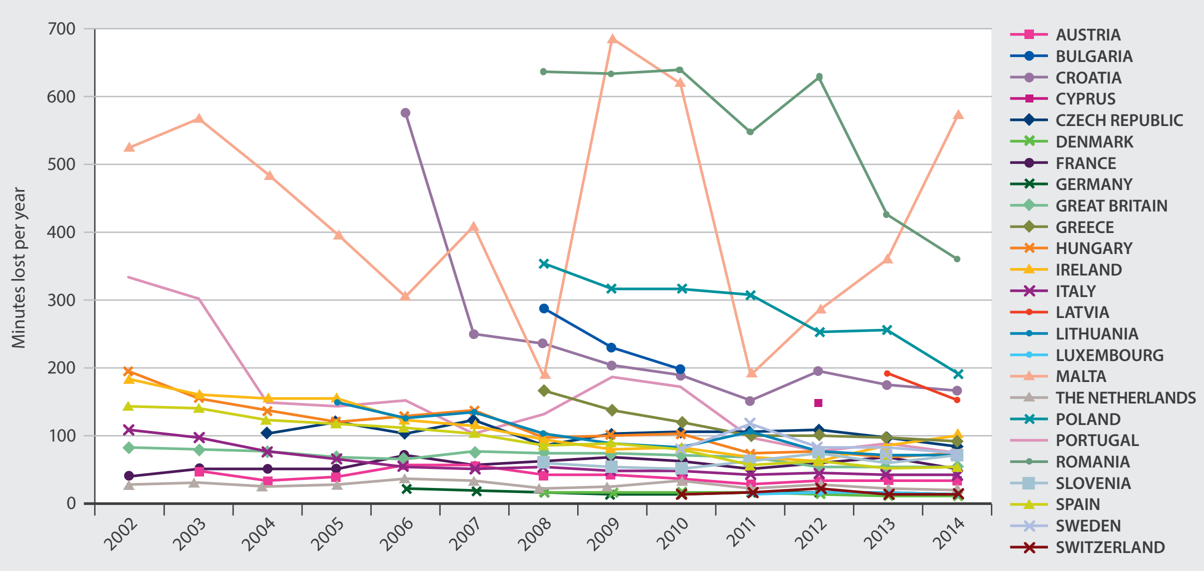


FIGURE 2.10 UNPLANNED LONG INTERRUPTIONS EXCLUDING EXCEPTIONAL EVENTS (MINUTES LOST PER YEAR); ONLY COUNTRIES NOT EXCEEDING 200 MINUTES

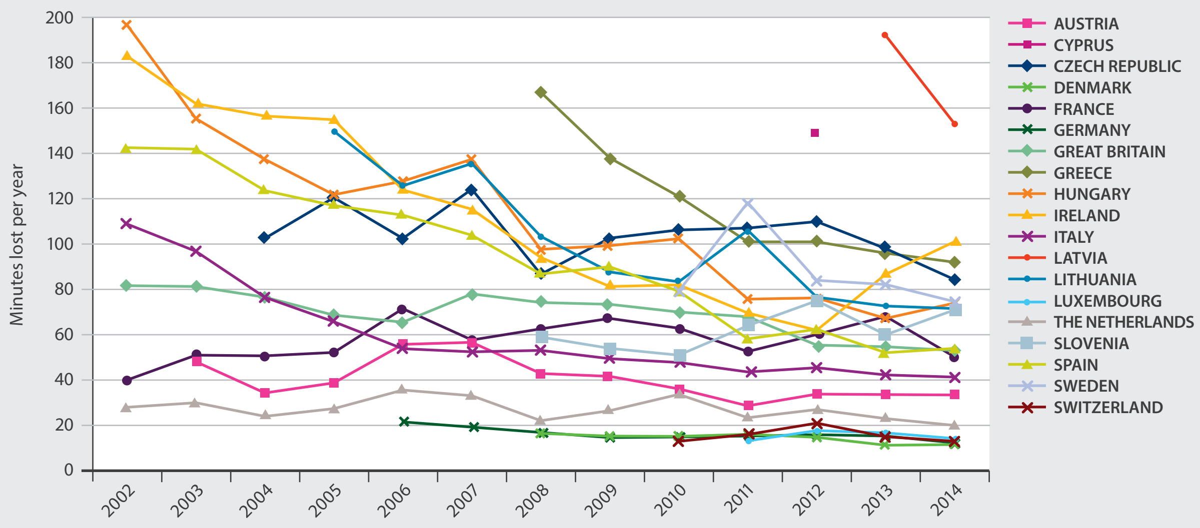


FIGURE 2.11 UNPLANNED LONG INTERRUPTIONS EXCLUDING EXCEPTIONAL EVENTS (NUMBER OF INTERRUPTIONS)

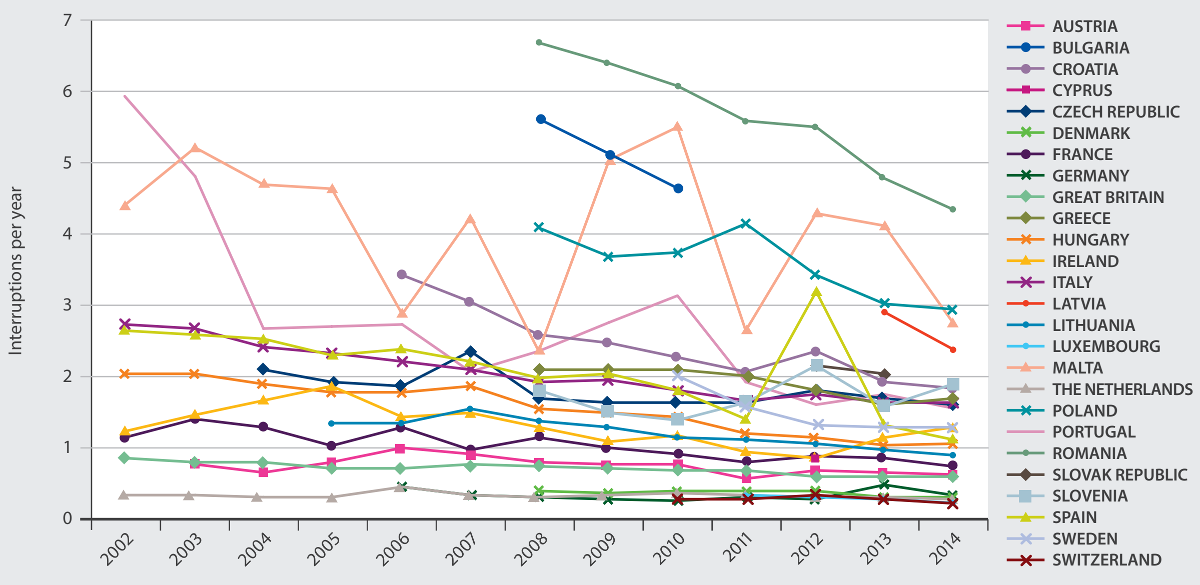


FIGURE 2.12 UNPLANNED LONG INTERRUPTIONS EXCLUDING EXCEPTIONAL EVENTS (NUMBER OF INTERRUPTIONS); ONLY COUNTRIES NOT EXCEEDING 3 INTERRUPTIONS

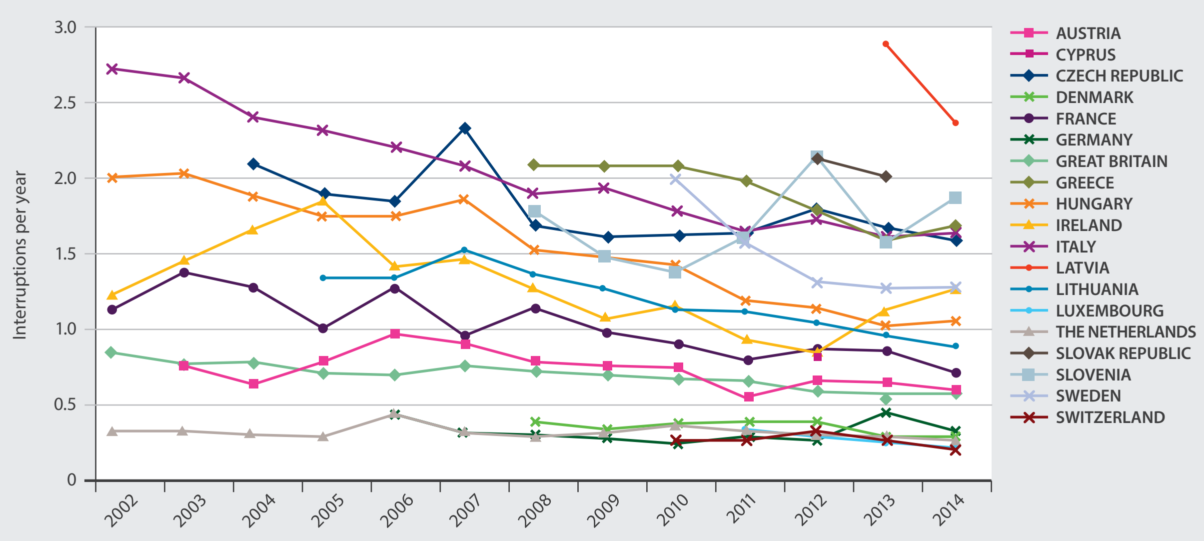


Figure 2.11 shows the number of long interruptions per year, excluding exceptional events. Considering the data reported for the years since the publication of the 5th Benchmarking Report (2011, 2012, 2013 and 2014), we can observe either constant quality levels or a smooth general tendency for an increase in quality in nearly all countries.

2.6.3. Planned (notified) interruptions

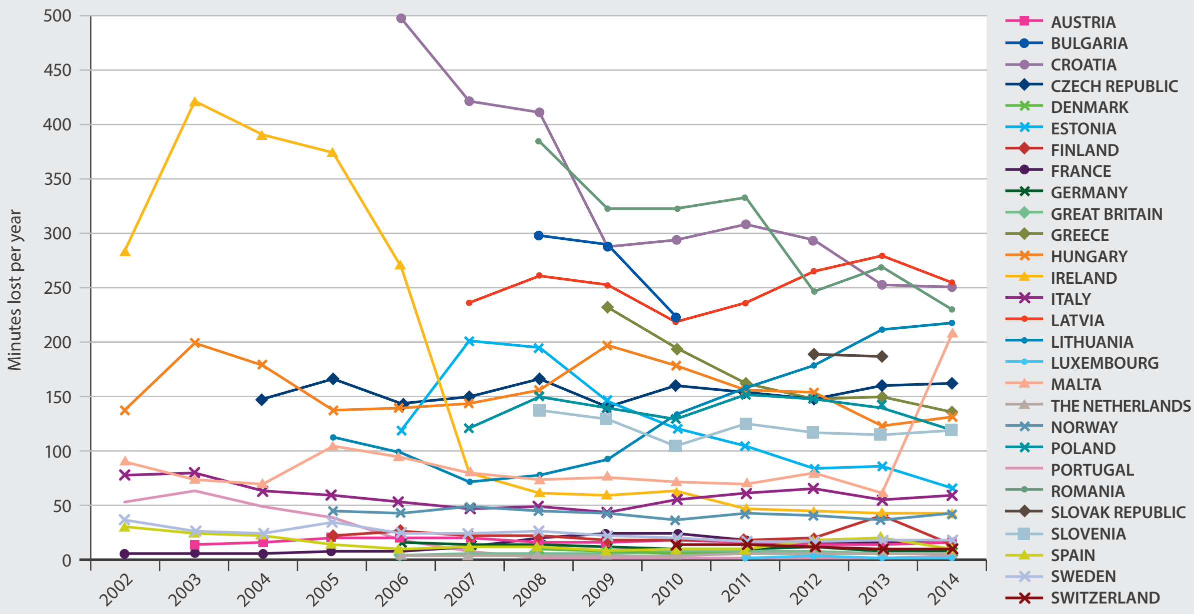
Planned interruptions relate to those minutes without supply experienced by network users who were given prior notice about the interruption. The general and national rules related to definition and treatment of this kind of interruption can be found in Section 2.4.2.

The minutes lost per year due to planned interruptions are presented in Figure 2.13 for the countries that reported the data. The value shows a very wide spread between the countries, from less than 10 minutes to over 500 minutes per year. No trends are visible in the figure; the minutes lost due to planned interruptions remain more or less constant during the observation period, although some countries show a minor reduction (Croatia, Greece, Estonia and Romania). Nevertheless, there are also exceptions, for example Lithuania's minutes lost significantly increased from 2007 to 2014.

The differences between countries may be due to variations in the design of the distribution network (with or without redundant supply paths) and the amount of maintenance and building in the distribution network. A temporary high level of planned interruptions could be a sign of high investment in the distribution networks, aiming at reducing the number of unplanned interruptions in the future. High levels of planned interruptions can also be due to replacement and repair of components that were provisionally restored after a major storm and due to a widespread replacement of energy meters.

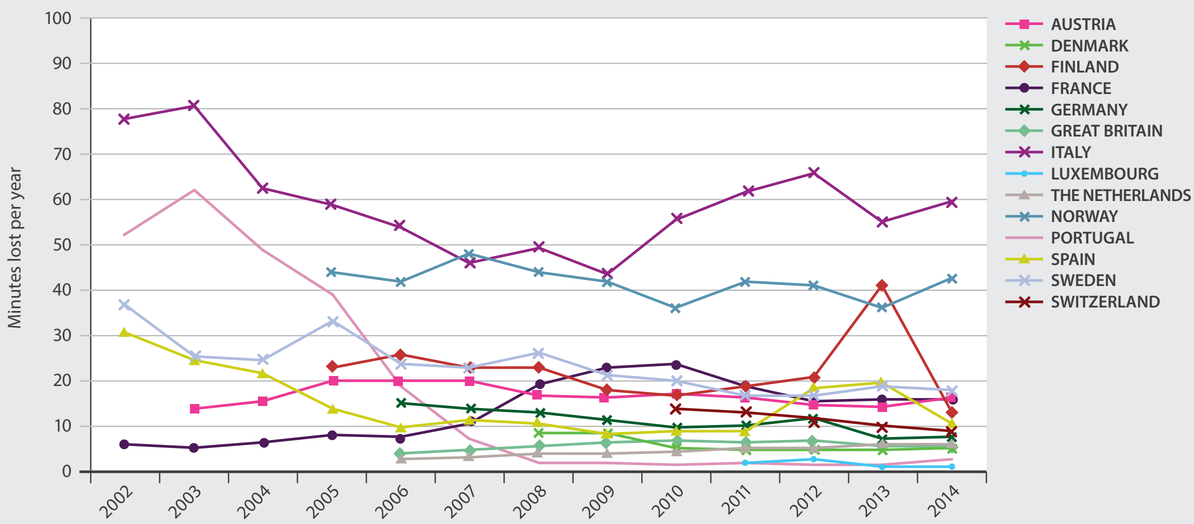
Not all countries include interruptions due to planned maintenance at LV in their statistics. Radial networks without redundancy, where planned interruptions are necessary for maintenance, are more common at low-voltage levels. Not including incidents at LV may significantly underestimate the number and duration of planned interruptions.

FIGURE 2.13 PLANNED LONG INTERRUPTIONS (MINUTES LOST PER YEAR)



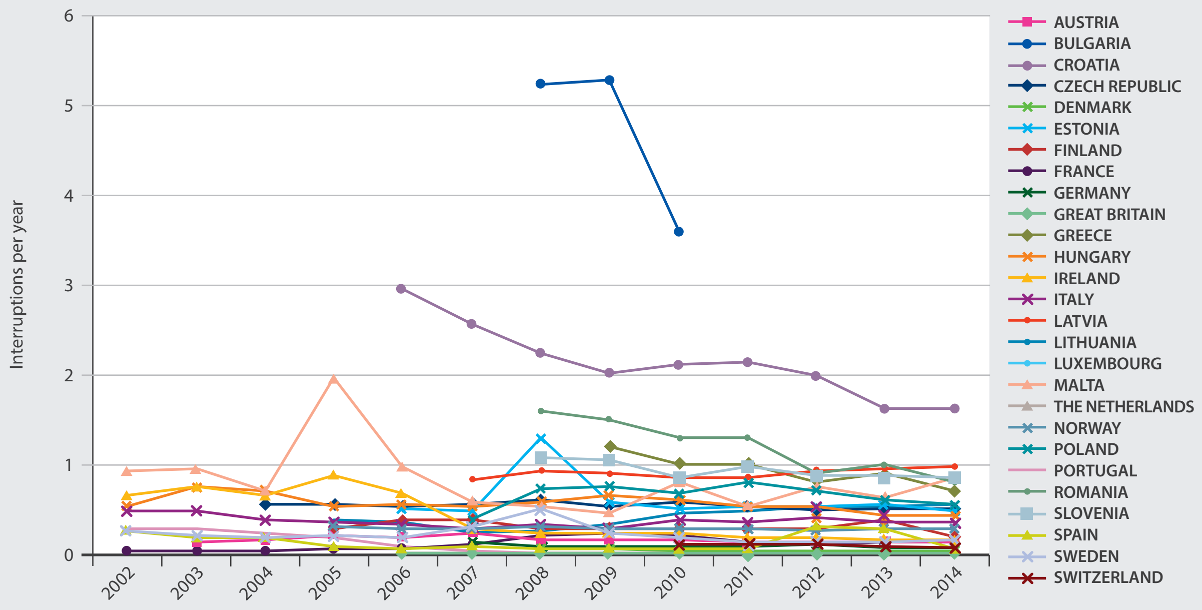
The values in Figure 2.13 are difficult to observe for countries with very few minutes lost per year during planned long interruptions. Therefore, Figure 2.14 shows only countries not exceeding a limit of 100 minutes lost per year. No trends are visible, except minor reduction in Germany, Norway and Switzerland and a minor increase in the Netherlands.

FIGURE 2.14 PLANNED LONG INTERRUPTIONS (MINUTES LOST PER YEAR); ONLY COUNTRIES NOT EXCEEDING 100 MINUTES



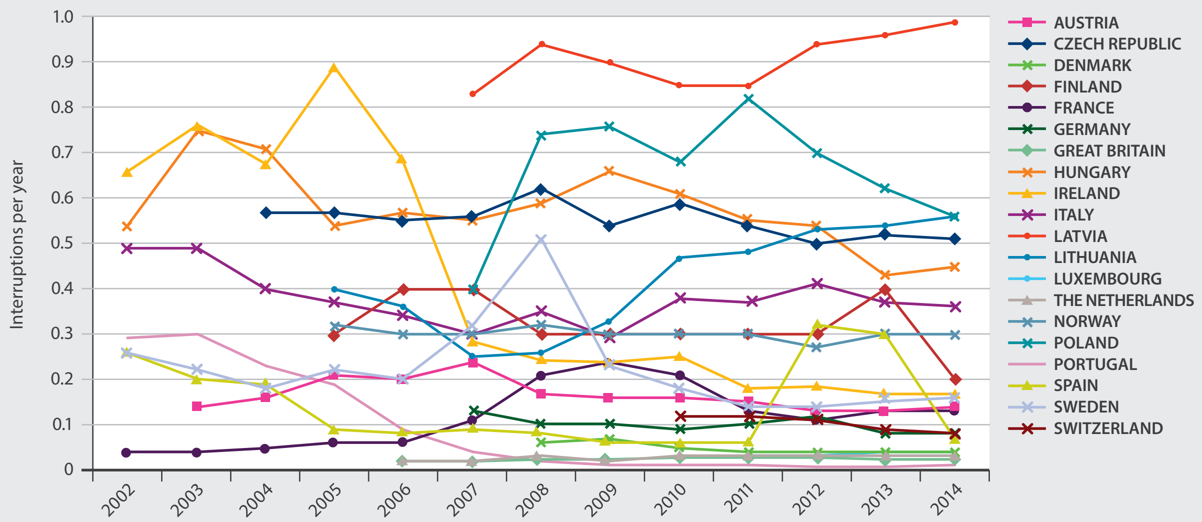
The number of planned interruptions per year is shown in Figure 2.15. As with minutes lost, the number of interruptions also varies significantly between countries and there is no visible trend; except for Croatia, Romania and Greece, where the duration of interruptions for the years reported has been decreasing.

FIGURE 2.15 PLANNED LONG INTERRUPTIONS (NUMBER OF INTERRUPTIONS)



Because of the significant variation between countries (Bulgaria reported very high values), only countries with values limited to 1 interruption per year are presented in Figure 2.16. Except for some countries with relatively stable values, it is hard to find trends.

FIGURE 2.16 PLANNED LONG INTERRUPTIONS (NUMBER OF INTERRUPTIONS); ONLY COUNTRIES NOT EXCEEDING 1 INTERRUPTION



2.6.4. Short interruptions

As previously illustrated, about half of the countries make no distinction between long and short interruptions. Additionally, few countries differentiate between interruptions lasting less than 1 second (or similar values), known as transient interruptions, and those lasting longer than 1 second and less than 3 minutes, which is the definition of a short interruption in most countries.

As discussed in Section 2.5, nearly all countries use the indicator for the average number of times per year that the supply to a network user is interrupted for 3 minutes or less (usually called MAIFI).

When calculating MAIFI, the time-aggregation rules are very important. Multiple interruptions during a 3 minute period, due to automatic reclosing actions, may be counted as one event for MAIFI or as multiple events. This choice could significantly impact the value of MAIFI. In fact, MAIFIE (Momentary average interruption event frequency index, according to the term used in CENELEC TR 50555) is used in practice in most countries for the average frequency of momentary interruptions. In addition, when calculating MAIFIE, the aggregation rules used for counting short interruption sequences are very important and can greatly affect the calculated values.

2.6.5. Interruptions on the transmission networks

As mentioned in Section 2.5.1, the most common indicators for measuring continuity of supply in transmission networks are ENS and AIT. ENS gives the total amount of energy that would have been supplied to the interrupted users if there had not been any interruption. AIT is expressed in minutes per year and calculated as 60 times the ENS (in MWh) divided by the average power supplied by the system (in MW). CEER's data survey aimed to collect ENS and AIT indices for both long and short interruptions[3]. Table 2.11 reports the ENS data available from 11 countries. The AIT data available are presented in Table 2.12. Even though the number of countries is similar (10), there are differences in responding countries between these 2 tables.

The definition of the transmission network can significantly affect comparisons. Whereas in most countries the transmission network includes EHV and HV, the transmission network in the Czech Republic (plus selected 110 kV lines), Great Britain, Hungary, Norway (plus selected 132 kV lines), Romania, the Slovak Republic, Spain and Sweden mostly corresponds to EHV. For exact definitions, please refer to Table 2.3 in Section 2.4.3.

TABLE 2.11 UNPLANNED ENERGY NOT SUPPLIED (ENS) IN MWH DUE TO INTERRUPTIONS IN TRANSMISSION NETWORKS (EXCLUDING EXCEPTIONAL EVENTS)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cyprus											202.8		
Czech Republic								52	7	161.3	4.5	167.5	231
France	1,753	3,211	1,891	1,598	1,416	1,815	3,563	5,089	2,429	1,374	1,864	2,499	2,150
Greece									1,245	2,070.7			
Italy					3,477	8,465	2,430	2,372	2,175	3,131	3,886	2,839	1,593
Latvia											2,533	1,395	1,144
Lithuania				57.04	157.55	133.89	15.39	26.32	52.95	51.18	18.79	13.89	37.35
Portugal	75.9	141.78	496	40.2	262.59	75.9	130.16	42.09	116.2	27.00	0	8.6	1.8
Romania			247	387	106	80	167	55	267.9	98.804	102.71	30.89	82.51
Slovenia		2.33	94.54	2.54	156.76	34.02	1.34	7.69	67.94	9.71	8.85	25.69	0.82
Spain	802.69	466.23	1,249.65	548.79	935.8	757.16	573.54	437.5	1,569.47	2,590	113	1,126	204

Notes:
France: since 2008, ENS & AIT include load shedding. Includes big incidents in south-east of France in 2008 and 2009.
Latvia: This is only for MV and LV together. NRA does not hold information for transmission system.
Portugal: interruptions not attributable to force majeure or exceptional events. The 2006 value considers the interruptions due to the European event of 4th November (204.5 MWh).
Slovenia: does not comprise the interruptions attributable to a third party. Interruptions on EHV and HV are counted in.
Spain: only for Spanish peninsular system.

3. ENS can be applied to both long and short interruptions in the countries where these interruption types are defined. This is different to the computation of the SAIDI indicator for distribution networks, which normally refers only to long interruptions. The different definition can be associated to the meshed nature of transmission networks, which normally leads to shorter interruption times compared to those of interruptions in radial distribution networks. As a consequence of shorter interruption times, the impact of short interruptions in ENS and AIT indicators tends to be greater than their impact in the SAIDI index.

TABLE 2.12 UNPLANNED AVERAGE INTERRUPTION TIME (AIT) IN SYSTEM MINUTE PER YEAR DUE TO INTERRUPTIONS IN TRANSMISSION NETWORKS (EXCLUDING EXCEPTIONAL EVENTS)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium							3.02	1.35	4.25	1.67	2.18	1.77	3.47
Cyprus											1,433		
Czech Republic								5.3	5	15.4	4	18.3	15.8
Estonia						234	1,209.8	1,068	2,972.32	2,983.33	1,756	2,719	410.3
France	2.4	4.2	2.4	2	1.8	2.3	4.4	6.4	2.9	1.7	2.3	3.0	2.8
Lithuania				1.62	5.11	3.98	0.64	0.78	2.22	2.31	0.87	0.65	1.75
Portugal	1.07	2.02	6.68	0.52	0.78	0.81	1.35	0.44	1.16	0.28	0	0.09	0.02
Romania			3	4.4	1.2	0.86	1.8	0.81	3.1	1.06	1.19	0.35	0.82
Slovenia		0.1	4.03	0.11	6.33	1.35	0.06	0.36	2.95	0.4	0.37	1.08	0.03
Spain	2.006	1.095	2.798	1.176	1.939	1.523	1.147	0.91	3.17	0.42	0.18	0.24	0.441

Notes:
Belgium: only refers to the interruptions for which the responsibility is linked to the TSO.
Czech Republic: Average interruption time of one interruption.
France: since 2008, ENS & AIT include load shedding. Includes big incidents in south-east of France in 2008 and 2009.
Portugal: interruptions not attributable to force majeure or exceptional events. The 2006 value considers the interruptions duo to the European event of 4th November (2.75 min).
Slovenia: does not comprise the interruptions attributable to "third party". Interruptions on EHV and HV are counted in
Spain: only for Spanish peninsular system. Data for 2014 are provisional data pending audit.

2.6.6. Technical characteristics of electricity networks

European networks are designed in various ways, which can be explained by different factors such as the population density, the country's topology, climate and the history behind the construction and evolution of the electricity networks. There is a large variety of parameters for the definition of the technical state of networks. These may vary widely in different countries and may have an impact on continuity of supply.

Figure 2.17 and Figure 2.18 below and Table 2.13 show the length of circuits in European countries in a year when the latest data for all voltage levels was available (for most countries this is 2014). For low and medium voltage, in addition to total length of circuits, the respective lengths of cables and overhead lines are also included. Again, voltage levels often have different meanings across countries and Table 2.3 should always be consulted.

TABLE 2.13 LENGTH OF CIRCUITS IN EUROPEAN COUNTRIES IN KM

	LV				MV				HV	EHV
Country	Total length of circuits	Length of cable circuits	Length of overhead lines	Percentage of under-ground cables	Total length of circuits	Length of cable circuits	Length of overhead lines	Percentage of under-ground cables	Total length of circuits	Total length of circuits
Austria, 2014	170,663	135,337	35,326	79.3%	68,684	41,146	27,538	59.906%	11,275	6,729
Belgium, 2014	128,120	79,044	49,076	61.695%	75,286	69,532	5,754	92.357%	9,604	1,761
Bulgaria, 2010	88,937	26,044	62,893	29.28%	63,946	14,354	49,592	22.447%	15,213	
Croatia, 2014	95,174	27,521.6	67,652.4	28.917%	40,600	16,637	23,963	40.978%	6,401	1,247
Cyprus, 2012	14,924	5,366	9,558	35.96%	9,304	3,608	5,696	38.78%	1,621	
Czech Republic, 2014	149,759	85,071	64,688	56.805%	76,815	17,865	58,950	23.257%	14,101	5,503
Denmark, 2011	95,797	92,431	3,366	96.49%	72,237	64,017	8,220	88.62%	2,992	
Estonia, 2014	36,781	10,531	26,250	28.63%	31,348	8,798	22,550	28.066%	3,547	1,945

	LV				MV				HV	EHV
Country	Total length of circuits	Length of cable circuits	Length of overhead lines	Percentage of underground cables	Total length of circuits	Length of cable circuits	Length of overhead lines	Percentage of underground cables	Total length of circuits	Total length of circuits
Finland, 2014	239,960	97,817	142,143	40.76%	141,290	23,166	118,124	16.4%	16,134	7,378
France, 2014	706,106	302,556	403,550	42.85%	626,836	288,208	338,628	45.978%	55,221	49,687
Germany, 2013	1,156,785	1,029,542	127,243	89.0%	509,866	398,232	111,634	78.105%	96,308	34,797
Great Britain, 2014	389,663	328,850	60,813	84.39%	326,714	158,763	167,951	48.59%		72,938
Greece, 2014	124,575	78,507	46,068	63.02%	110,750	11,920	98,830	10.763%	12,733	4,699
Hungary, 2014	88,700	23,841	64,859	26.878%	67,400	13,480	53,920	20.0%	6,520	4,855
Ireland, 2014	70,460	12,362	58,098	17.54%	92,326	9,526	82,800	10.318%	7,266	6,500
Italy, 2014	857,977	320,578	537,399	37.364%	388,762	173,660	215,102	44.67%	46,575	21,931
Latvia, 2014	58,960	21,482	37,478	36.435%	35,647	6,456	29,191	18.11%	3,963	1,394
Lithuania, 2014	71,078	16,867	54,211	23.73%	56,004	12,516	43,488	22.35%	6,792	
Luxembourg, 2014	6,069	5,724	345	94.315%	3,705	2,612	1,093	70.5%	536	156
Malta, 2014	3,028.2	951.2	2,077	31.41%	1,380.4	1,295.5	84.9	93.85%	61	0
The Netherlands, 2014	145,712	145,712	0	100%	105,181	105,181	0	100%	10,559	2,974
Norway, 2013	199,074	106,030	93,044	53.26%	100,481	40,859	59,622	40.66%	22,159	8,261
Poland, 2014	424,540	179,613	244,927	42.31%	294,998	71,491	223,507	24.234%	33,103	13,688
Portugal, 2014	141,829	33,243	108,586	23.44%	72,319	14,135	58,184	19.545%	9,375	8,630
Romania, 2014	183,279	50,562	132,717	27.587%	120,038	29,023	91,015	24.178%	22,300	8,721
Slovak Republic, 2013	52,863	13,396	39,467	25.34%					32,720	9,663
Slovenia, 2014	46,272	18,272	28,000	39.49%	17,391	5,448	11,943	31.33%	2,705	997
Spain, 2014	443,764	189,273	254,491	42.65%	248,756	92,855	155,901	37.33%	28,277	42,601
Sweden, 2014	314,786	250,149	64,637	79.47%	199,104	116,289	82,815	58.41%	30,404	15,314
Switzerland, 2014	136,200	125,900	10,300	92.44%	44,000	32,800	11,200	25.45%	9,000	6,750

Notes:
Great Britain: Medium voltage is not defined in Great Britain. High voltage starts at 1 kV and goes up to (but not including) 22 kV. In this table, the voltage defined as HV in Table 2.13 is included as MV since the voltage level roughly corresponds to other MV systems in Europe. The HV value was left blank.

The following 2 figures illustrate the length of low and medium voltage circuits in European countries corresponding to the years listed in Table 2.13. They are ordered by the total length of LV and MV circuits in descending order. Germany, France and Italy are the top 3 countries in both cases.

FIGURE 2.17 LENGTH OF LV CIRCUITS (KM)

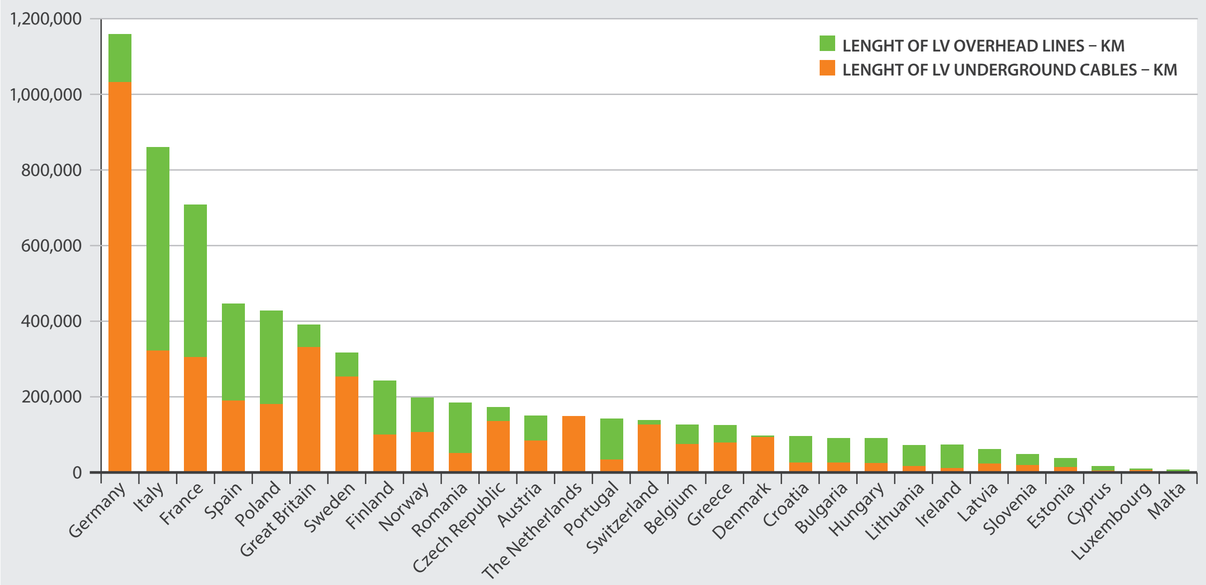


FIGURE 2.18 LENGTH OF MV CIRCUITS (KM)

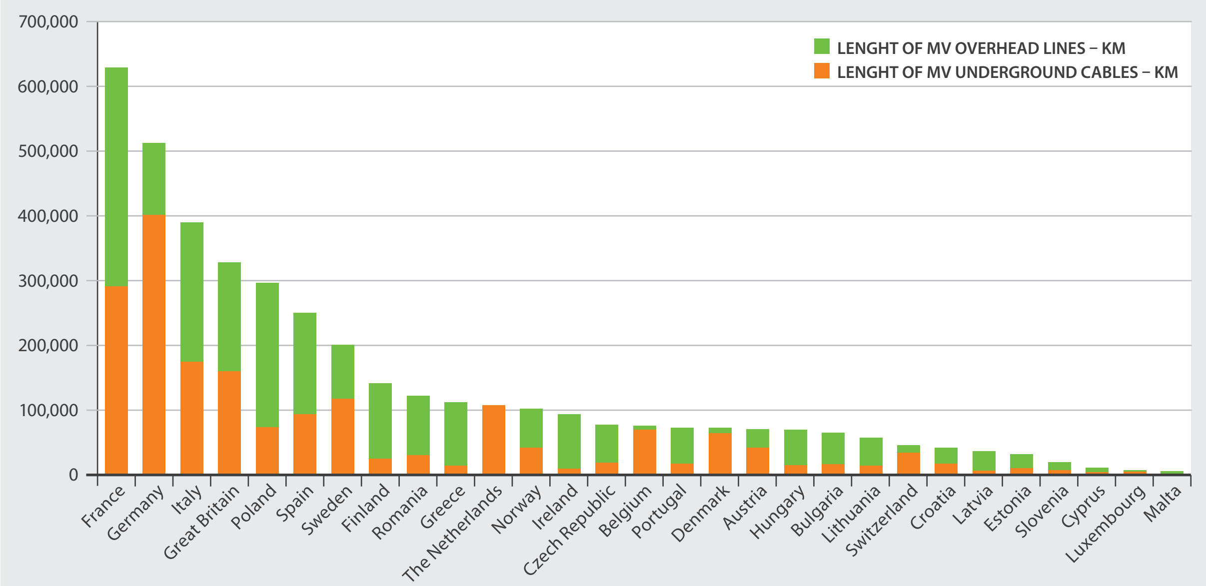


Figure 2.20 graphically illustrates the percentage of the share of cable lines at MV and LV. Groups of countries that have similar network characteristics may make it easier to compare the values of their indicators. The proportion of cable circuits has direct impact on continuity of supply indicators. Generally speaking, the countries that have high percentage of cable circuits (especially at MV) have lower values of the corresponding interruption indicators. This is obvious when rates of underground cables from Figure 2.19 and Figure 2.20 are compared to the values of indicators in Section 2.6.

FIGURE 2.19 RATE OF LV AND MV UNDERGROUND CABLES (1)

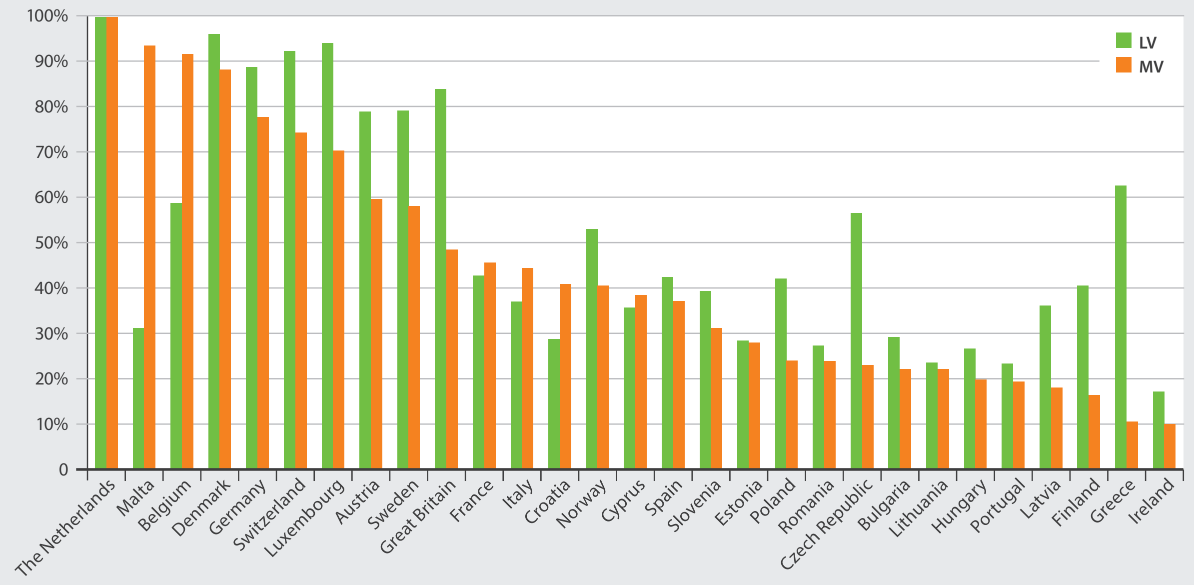
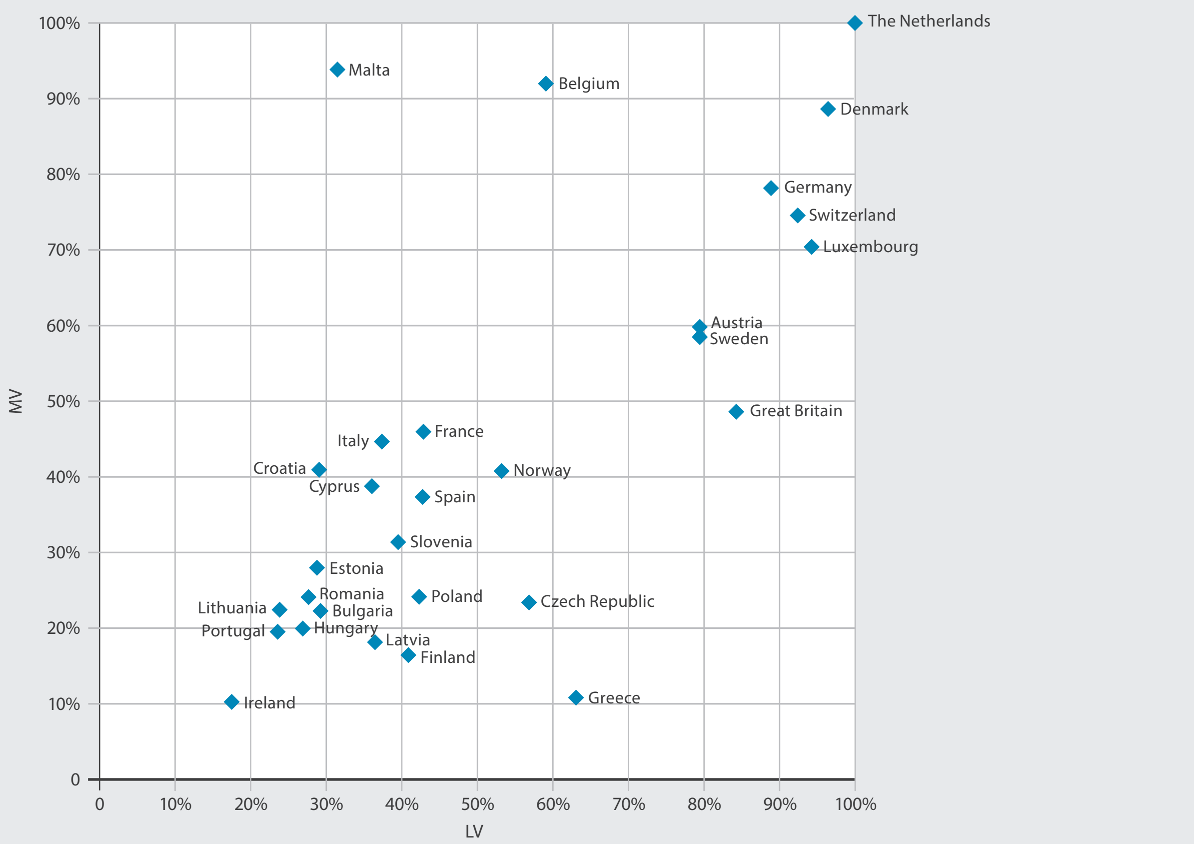


FIGURE 2.20 RATE OF LV AND MV UNDERGROUND CABLES (2)



2.7. STANDARDS AND INCENTIVES IN CONTINUITY OF SUPPLY REGULATION

2.7.1. Introduction

This section provides an overview of the existing quality regulation frameworks in European countries, for electricity distribution as well as for transmission networks. Financial incentives discussed in this chapter relate to continuity of supply. For economic penalties and compensations in the field of commercial quality, see Chapter 4.

A performance-based regulation comprises the following main aspects:

- **Continuity measurement** – a prerequisite for setting standards and reward/penalty regimes. Here, robust and reliable data is needed in terms of the actual continuity levels as well as the level perceived by the network users;

- **Maintenance and improvement of general continuity levels** – the investment decisions of network operators influence current and future quality levels. Depending on the actual quality level, the NRA must make sure that the current status is either maintained (if continuity of supply has already reached good levels) or improved (if continuity of supply is not yet satisfactory). Preferred regulatory actions to reach these goals include publishing continuity data and implementing reward/penalty schemes. Regulatory approaches for general continuity levels are addressed in Section 2.7.3; and

- **Continuity ensured for each network user** – the focus is placed on individual users. Minimum standards for quality levels accompanied by associated payments will guarantee that single users will be compensated if the standard is not met by the network operator. Regulatory approaches on individual continuity levels are discussed in Section 2.7.4.

2.7.2. Measurement of quality levels: a prerequisite for quality regulation

The measurement of actual continuity levels through indicators and standards constitutes the basis for regulating continuity and quality of supply as a whole. In general, the actual measurement of continuity can be performed on 2 different levels, namely system level and user-specific level. While the measurement at system level is usually done on an aggregate basis, measurement at user level is often based on surveys asking customers about their satisfaction, expectations, willingness to pay for high quality or willingness to accept low quality levels. As is to be expected, private households and business or industrial consumers can have diverging interests and therefore will probably also have diverging views regarding the required quality of electricity supply. The implementation of adequate measurement systems is essential for setting standards and incentives at both measurement levels.

The most common indicators for measuring duration and frequency of continuity of supply are SAIDI and SAIFI for distribution networks and ENS and AIT for transmission networks. The measurement of interruptions should cover all network levels.

2.7.3. Regulation at system level and reward/penalty regimes

The following section provides an overview of the existing quality incentive schemes across Europe. It also illustrates which indicators and standards are used in this regard. In addition, the economic effects and outcomes of the regulatory actions are addressed.

General reward or penalty schemes or incentives to optimise continuity of supply levels have been introduced in 17 of the 26 countries that provided feedback: Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Italy, the Netherlands, Norway, Portugal, Slovenia, Spain and Sweden. However, the use of rewards, penalties and a combination of those differs among countries and is also applied differently to the transmission and the distribution levels. Penalties are usually coupled with rewards and can be applied to distribution or transmission networks or both. Table 2.14 reveals that countries do not use the same indicators. Most of the countries that have not yet implemented a continuity of supply scheme either consider, plan or have intentions to introduce such a regime (e.g. Austria, Greece, Luxembourg and Romania).

Quality as a regulatory element has been implemented in several regimes across Europe, with incentive schemes being the most common ones. The main intention is to keep quality levels at a socio-economically acceptable level. As such, maintaining or improving the existing levels might be on the NRA's radar. Nevertheless, the input-output relationship has to be considered: if the quality level is already very high, then a further improvement might be very costly for the consumer. Existing schemes are reviewed below. The analysis focuses on transmission and distribution networks separately.

TABLE 2.14 CONTINUITY OF SUPPLY REGULATION AT SYSTEM LEVEL

System	Rewards	Penalties	Combination	Continuity indicators used
Distribution		DK, HU	BG, CZ, DE, ES, FI, FR, GB, IE, IT, NL, NO, PT, SI, SE	BG (SAIDI, SAIFI), CZ (SAIFI, SAIDI), FI (outage costs based on planned and unplanned long interruptions), FR (SAIDI), DE (SAIDI for LV, ASIDI for MV), GB (customer interruptions and customer minutes lost), HU (SAIDI, SAIFI, outage rate), IE (customer minutes lost, customer interruptions), IT (SAIDI and SAIFI+MAIFI), NO (interrupted power at a specific time, duration, time of occurrence, planned, unplanned), PT (END), SI (SAIDI, SAIFI), ES (TIEPI, NIEPI), SE (ENS, PNS, SAIDI, SAIFI, CEMI4)
Transmission	BE, ES	HU	DE, FI, FR, IE, IT, NO, PT, SE	BE (AIT), FI (outage costs based on planned and unplanned long and short interruptions), FR (AIT and SAIFI+MAIFI), DE (SAIDI for LV, ASIDI for MV), HU (outage rate, AIT), IE (system minutes lost), IT (ENS), NO (interrupted power at a specific time, duration, time of occurrence, planned, unplanned), PT (TCD: Combined average availability rate in %), ES (availability of facilities), SE (ENS, PNS)
No existing CoS scheme	AT, CH, CY, EE, EL, LT, LU, MT, PL, SK			
Intentions/plans for implementation	AT (details under consideration), EL (penalty and reward scheme on basis of SAIFI and SAIDI indicators), LU (Q factor currently under discussion), RO (implementation under consideration)			

Belgium introduced for the period 2016-2019 an incentive to improve the continuity of supply of the transmission system. The TSO can obtain a bonus up to 2 million €/year based on the AIT of the transmission system. The formula that will be applied to calculate the bonus is:

$$Bonus\ = \min\left(2\ M€, 1.2\ + \log\left(\frac{AITref}{AIT(y)}\right) * AITref * IR(y)\right)$$

Where:
$AITref$ is the reference AIT (set at 2.55);
and $AIT(y)$ is an incentive rate that is a function of the energy offtake of the grid for a given year.

Bulgaria uses a combination of penalties and incentives for continuity regulation for distribution companies (no existing scheme for the transmission level) on the basis of SAIFI and SAIDI indicators. The scheme is based on cost estimation survey and an optimal continuity level has been estimated. Each year, the level of the performance indicators is determined according to a standardised calculation method which is the same for the whole country. However, the indicators are different for each company. Calculated company values are then compared to determined target indicators. The scheme requires a minimum improvement which is calculated according to the following formula:

$$K = \frac{(RV - TV)}{TV}$$

The correction ratio for the performance of the indicators (K) is determined as the ratio of the difference between the reached value for the reference year (RV) and the target value (TV) divided by the respective target value. A maximum value is determined for each company based on a comparative analysis of EU countries' practices for reached indicators in similar energy companies. Moreover, the NRA takes into account the realised investments of the relevant companies. The continuity scheme is linked to the revenue-cap formula and the incentive is funded by all customers.

The Czech Republic relies on a combination of rewards and penalties for continuity regulation for distribution companies on the basis of SAIDI and SAIFI (only events which can be influenced by the DSOs, i.e. those under standard weather conditions and planned interruptions). An analysis of the dependency between costs and quality was made and the company specific target value of SAIFI, SAIDI for given price control period is set on the basis of this analysis. A minimum improvement is foreseen, as otherwise the Q-element, which is linked with the regulatory formula, will result in a penalty. Furthermore, the scheme involves a dead band which is set as a percentage from the required value of the indicator and a 2 year moving average, whereby the goal is to eliminate year to year fluctuations. In this sense, the incentive formula uses a linear dependence between quality and reward/penalty with the dead band and the maximum reward/penalty limit, whereby the target which was set in advance is compared with average value of actual performance indicators in the past 2 years. Target values are updated at the beginning of the regulatory period, but the comparison happens on an annual basis. The financial result is set to +/- 2% of DSO's profit for each indicator and the maximal value of the reward or penalty is set as a percentage of the requested value of the indicator. The incentive scheme is funded by customers of DSOs which are entitled to incentives. More information can be found in a case study at the end of the chapter on continuity of supply, in Section 2.9.1.

While **Denmark** does not monitor the TSO, it uses a regime which exclusively focuses on penalties for DSOs. The Danish NRA did not conduct a cost estimation survey or estimation of an optimal continuity level. The implemented scheme does not foresee a minimum improvement or dead band. It is not based on a cost estimation survey or estimation of a socioeconomic or optimal continuity level, but the desired continuity level is set at 83%. An individual threshold (IT) value for each network company is calculated on an annual basis. If the interruption frequency or duration is higher than the IT, the company gets a penalty. The penalty is calculated as the minimum of the 2 values – 10% of the excess of the IT or 1% of the susceptible costs. The company can get a penalty for both frequency and duration. The maximum penalty is 2% of the susceptible costs, whereby there are caps of 1% for both frequency and duration to prevent too high penalties.

The scheme in **Finland** is based on a combination of rewards and penalties which provide incentives to optimise future continuity of supply levels on the transmission as well as on the distribution level. The indicators used are planned and unplanned long term interruptions for transmission companies and planned and unplanned long and short term interruptions for distribution networks. Corresponding outage costs are taken into account.

In 2009, the Finnish NRA conducted 2 different cost estimation surveys which form the basis for the design of the continuity scheme of electricity TSOs. The first survey was made by Tampere and Lappeenranta University of Technology and the other survey was made by Pöyry Management Engineering. These surveys were mainly based on interviews and the analysis of industrial data. For electricity DSOs, an initial survey was made in 2005. The research was made by Helsinki and Tampere University of Technology and it was mainly based on a postal inquiry and telephone interviews. Another survey was made in 2014 which affirmed that the results from the previous survey are still accurate enough to be used in regulation. The actual continuity of supply level of each network operator (TSOs and DSOs), which is calculated from historical values, is compared to a set reference level, whereby no area difference is taken into account. If the actual level is better than the reference, the network operator will get a lower adjustment of the profit (reward); otherwise it will be penalised. While the incentive scheme for TSOs involves the use of a dead band in which the economic effect is set to zero, there is no dead band for DSOs. Moreover, there is a symmetric structure of maximum levels (cap and floor) used for penalties and rewards.[4]

As in many other countries, **France** uses a combination of rewards and penalties for both distribution and transmission network continuity regulation. While AIT and SAIFI+MAIFI are the continuity indicators used for the transmission level, SAIDI is addressed at distribution level. No cost estimation surveys or estimations of optimal levels were carried out for the development of the continuity scheme. The expected level of continuity is estimated in line with the investment program of the distribution and transmission companies and past values of indicators considered in the incentive scheme. No difference is made between rural and urban areas. While the incentive scheme does not require a minimum improvement of continuity at TSO level, it is required for distribution companies. For the transmission company, the expected level of continuity, i.e. the level that corresponds to no penalty and no reward, is set at 2.4 minutes for the period between 2009 and 2012. For distribution companies, the expected level of continuity (i.e. the level that corresponds to no penalty and no reward) is set at 68 minutes for 2014, 67 minutes for 2015, 66 minutes for 2016 and 65 minutes for 2017. No tolerance/dead band is implemented for either the DSO or TSO level. The incentive rate for TSO and DSOs is calculated according to formulas 1 and 2 respectively:

$$(1)\quad I_N = -10{,}4 \times AIT_{ref} \times \ln\left(\frac{AIT_N}{AIT_{ref}}\right) + 72 \times (SAIFI + MAIFI)_{ref} \times \ln\left(\frac{(SAIFI + MAIFI)_N}{(SAIFI + MAIFI)_{ref}}\right)$$

$$(2)\quad I_N = -4{,}3 \times \left(SAIDI_{N\,ref} - 34\right) \times \ln\left(\frac{SAIDI_N - 34}{SAIDI_{N\,ref} - 34}\right)$$

4. Further details for the TSO and DSO schemes can be found in the following 2 documents:
http://www.energiavirasto.fi/documents/10179/0/Appendix_1-Confirmation_decision_Methods_of_determining_reasonable_return_2012-2015_TSO.pdf
http://www.energiavirasto.fi/documents/10179/0/Appendix_1-Confirmation_decision_Methods_of_determining_reasonable_return_2012-2015_DSOs_+revised-29112013.pdf

Where:

I_N	is the incentive of the year N (reward if positive; penalty if negative);
AIT_N	is the system average interruption time for the year N (excluding planned interruptions and exceptional events);
AIT_{ref}	is the reference system average interruption time set at 2.4 minutes;
$SAIFI+MAIFI_N$	is the system average number of times per year that the supply to a customer is interrupted (including short and long interruptions);
$SAIFI+MAIFI_{ref}$	is the reference average number of times that the supply to a customer is interrupted and is set to 0.6; $SAIDI_N$ is the system average interruption duration index for the year N (including interruptions for works); and
$SAIDI_{N\,ref}$	is the reference system average interruption duration index for the year N set at 68 minutes for 2014, 67 minutes for 2015, 66 minutes for 2016 and 65 minutes for 2017.

Moreover, while the incentive for TSOs is €10.4M/min and €72.0M/interruption, the incentive of €4.3M/min for DSOs corresponds to a value of loss load of about €6/kWh. For TSOs, both penalties and rewards are capped at €30M. For DSOs, the cap for both penalties and rewards is set at €54.2M.

In **Germany**, quality regulation was implemented with the beginning of the year 2012. For the time being this system is valid just for electricity distribution system operators on LV (low voltage level) and MV (medium voltage level) with more than 30,000 customers although there is no exact legal distinction between DSOs and TSO. That means in general this system is valid for the TSO as well. One reason why it is not applied to the TSO is because there is no reliable data available concerning continuity level on high voltage level and extra high voltage level. The system is an addition to the incentive-based regulation, which was implemented in 2009. No cost estimation surveys or estimations of an optimal continuity level were conducted. Network operators are able to get a reward or a penalty which is dependent on their overall performance concerning continuity of supply in comparison to the other network operators. Overall performance of the network operator is measured by SAIDI on LV and ASIDI on MV. Each network operator is benchmarked against an individual reference level (SAIDIi*). Structural differences in overall reliability are taken into account when calculating the reference value. Therefore load density which is the ratio of peak load and geographic area is used. As a result of a regression analysis a load density-dependent reference value for each network operator is calculated. The difference between the continuity reference level and the network operator's current SAIDI level is transformed into a monetary amount – reward as well as penalty – by multiplication with a price of quality per unit and the number of customers connected to the network operator's grid. The cap and floor for rewards and penalties is set to a fixed percentage of allowed revenues. Thus, the continuity scheme is explicitly linked with the general revenue-cap formula and the amount of rewards and penalties are funded by redistribution of the revenues. The existing revenue-caps increase or decrease with quality of supply. The overall amount of revenues is not affected. The rewards and penalties are calculated according to the formula:

$$\text{REWARD/PENALTY} = (\text{SAIDI}_{i*} - \text{SAIDI}_{i}) \times \text{CUSTOMERS}_{i} \times \text{PRICE OF QUALITY}$$

Both the operator's continuity level and the continuity reference level are calculated as a mean of continuity indicators for the past 3 years to control for stochastic influences in network reliability. The price of quality is estimated by using a macroeconomic approach which is used to estimate the value of lost load (VoLL). Data will be taken from the national accounting. For each year belonging to the first regulation period the price of quality was set to €0.18 per minute of interruption per customer. No predetermined minimum improvement is required and no dead band is addressed. Improving or worsening quality is an optimization decision taken by the network operator. The aim of the quality regulation system in Germany is to achieve a socio-economically acceptable level of continuity of supply which is not set by the NRA.

Incentive rates in **Great Britain** are used to reward or penalise distribution companies based on their performance regarding continuity standards. The continuity indicators considered in the incentive scheme are customer interruptions (CI) and customer minutes lost (CML), but exceptional events are excluded. Respective cost estimations are conducted during the price control process and companies have to reach targets set during the price control process which are valid for 8 years. Each distribution network operator's (DNO) performance in comparison to their customer interruptions and customer minutes lost targets provides their resulting penalty or reward, whereby there is a limit to the penalty and reward (2.5% of Return on Regulatory Equity). Furthermore, the system does not involve a dead band.

The continuity regulation system in **Hungary** is exclusively based on penalties for transmission as well as for distribution companies. For the transmission level, the outage rate (the availability of energy, which is the ratio of ENS to available energy) and the availability indicator for transmission lines are used as the availability indicators of the network. In addition to the outage rate, SAIDI and SAIFI indicators are considered for distribution companies. No cost estimation survey or estimation of an optimal continuity level was carried out. The expected continuity level is calculated on a historical basis for each company. While the individual requirements for improvement of continuity levels are determined for each DSO, the TSOs do not have to achieve minimum levels of improvement. Penalties are limited and depend on the actual performance level and the standard (which was not fulfilled). DSOs have to pay 1-2% of the amount of network charges to customers. The actual performance of continuity standards is considered in the next year's price-cap calculation.

In **Ireland**, the continuity scheme is based on a combination of rewards and penalties and is comparable for transmission and distribution companies. There is a single transmission and a single distribution company operating in the region. While the indicator used for the TSO is the system minutes lost (SML), the indicators on the DSO level are the customer minutes lost (SAIDI) and the number of customer interruptions (SAIFI). At the TSO level, the targets for the SML incentive are set through reviewing outturn SML results and discussions with the TSO on expected SML results for the forthcoming year. While there is a dead band but no minimum improvement foreseen for TSOs, DSOs have to improve their continuity level on an annual basis (without a dead band), whereby targets have been set up to 2015 (there is no differentiation between urban and rural)[5]. The level of the reward depends on the amount by which the TSO or DSO has beaten the foreseen target. Each % over/under achievement is rewarded by a fixed amount. On the TSO level, the most recent incentive period (2009/2010) had a central target of 3.5 SML with an upper (maximum) value of 5.5 SML. If the TSO had gone above 5.5 SML it would have had to pay the full penalty amount. For DSOs, the annual payment/penalty for customer interruptions is limited to 1.5% of total annual DSO revenue. This limit is set at a level to ensure the payment is sufficient to incentivise the DSO, while also ensuring the reward/penalty is not overly onerous on either the DSO or its customers. The quality schemes for both TSO and DSO are linked to the respective revenue-caps, whereby the annual payment/penalty is calculated each year and netted off (or added to) the annual revenue the company can collect from its customers.

Incentive (reward/penalty) regulation for continuity of supply was introduced in **Italy** on distribution level in 2000 and is regularly updated every 4 years. In the beginning, only SAIDI was considered but since 2008, regulation based on SAIDI was complemented by rewards and penalties for SAIFI+MAIFI as well. Transmission quality has also been regulated with rewards and penalties since 2008. A survey for estimating customer interruption costs was carried out in 2003 and the results have been embedded for valuating both rewards and penalties. At distribution level, continuity targets are set at "district level" starting from the actual level reached in the previous regulatory period (for each district separately) and targeting a nation-wide reference level to be reached in 3 regulatory periods (4-years each) for SAIDI and in 4 regulatory periods for SAIDI+MAIFI. Nation-wide reference targets are differentiated only according to territorial density (i.e. nation-wide reference targets are the same for all districts having the same territorial density of which 3 levels are defined: urban, suburban, and rural areas). Planned interruptions and interruptions attributable to exceptional events are excluded from reward/penalty regulation. This also applies to interruptions generated in transmission grid which are excluded from interruptions considered for DSO reward/penalty mechanism. Penalties are used to reduce distribution tariff, whilst rewards imply a limited increase in distribution tariff. There is a cap for rewards and floor for penalties in order to reduce risk. A similar reward/penalty mechanism is applied to the TSO at system level for interruption generated in the transmission grid. Furthermore, a "mitigation" mechanism economically incentivises DSOs to provide help to the TSO (when interruptions occur in the Transmission grid) through MV reconfiguration in order to back-feed interrupted customers via a non-standard network scheme until the supply is restored in the transmission system.

In **Lithuania**, rewards or penalties (no distinction between urban and rural areas) are linked to a price-cap formula via a quality factor and are adjusted every 3 years. Thus, the incentive is funded by all customers via network tariffs.

While in **the Netherlands** there is no quality regulation implemented on the transmission level, the distribution level has a scheme based on the combination of rewards and penalties. Each DSO is compared to the average valuation of the quality level of supply and receives a reward or penalty depending on whether it performed better or worse than the average. The scheme is based on SAIFI and CAIDI indicators and provides an incentive to each DSO to deliver the optimal level of continuity of supply. A cost estimation survey was conducted in 2004 amongst household customers and small and medium-sized companies in the Netherlands. In 2009 the results of this survey have been updated. This update realigned key variables with current economic developments. It did not include a new customer survey. These results are used to determine the value of the quality level of supply, given a certain level of SAIFI and CAIDI. The survey results indicated that for certain levels of delivered quality there was no compensation required by the customers. For example: If households were to experience an interruption more often than once in the 8-year period, lasting less than 21 minutes in total, no compensation would be required. Each DSO receives a reward or penalty at the height of the difference between the actual company specific performance level (the valuation of the quality level of the DSO) and the average continuity level achieved by all DSOs, i.e. the average is used as a standard for the quality factor.[6]

5. Details in Section 9.1 of the CER decision on DSO revenue for the 2011 to 2015 period: http://www.cer.ie/en/electricity-distribution-network-decision-documents.aspx?article=0b278e96-80f5-43e1-80ab- b23423c3c34c.
6. For further details, please see the "Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances".

Thus, no minimum improvement of the continuity level is demanded as such. Furthermore, no distinction is made between urban and rural areas. In this sense, no optimal continuity level is estimated as the regulation as such, but the incentive scheme should result in and optimal level of continuity of supply. The incentive is capped at 5% of the total income of the DSO. However, this cap has not been reached yet. The quality incentive scheme is linked to the price control formula, since the efficiency factor and the quality factor are both in the same formula to determine the total income of the DSOs. The efficiency factor is derived by considering the average costs of all DSOs as efficient and the quality factor is derived by considering the average value of quality as the standard. This way each DSO has to balance between efficiency and quality in such a way so that the optimal level of quality will be reached.

The **Norwegian** financial incentive-based regulation on continuity of supply (CENS) gives the network companies (TSO and DSO level) economic motivation to ensure an optimal resource allocation when all minimum requirements are complied with. The objective is to achieve the most optimal level of continuity of supply for the society as a whole. The customers' costs related to interruptions are detected through nationwide surveys and will vary between different customer groups, when the interruptions occur etc. The costs related to investments to reduce the extent of interruptions will on the other hand depend significantly on the location of the customers' connection to the power system, including network topology, geography, climate etc. From the NRA's point of view it is important that decisions influencing the continuity of supply are also based on cost-benefit analyses.[7] Thus, the costs related to decreasing the extent of interruptions must be lower than the future decrease in customers' interruption costs due to the investment. Incentives to optimise the continuity of supply levels, should take into account all cost elements. Consequently, for some customers this may imply reduced, increased or maintained CoS levels. No minimum requirements and no caps or floor are addressed in the schemes. For both TSOs and DSOs, the indicators used include interrupted power at a specific reference time, duration, time of occurrence (during the day, during the week, calendar month), whether the interruption was notified in advance or not.

Portugal defined 2 incentive schemes (for the TSO and DSO responsible for HV and MV) based on rewards and penalties. Dead bands are used to avoid the activation of the incentives when small performance improvement or deterioration is experienced. The incentive for the TSO has the objective of increasing the availability of network equipment, where the relevant indicator corresponds to the combined average availability rate (TCD), expressed in (%), which results from the weight of the average availability rate of line circuits and power transformers. The incentive for the DSO intends to improve the continuity of supply of the MV customers. This incentive consists of 2 components with different objectives: (1) to improve the overall continuity of supply; and (2) to improve the continuity of supply of the worst-served 5% of customers. The parameters of the 2 incentive schemes (TSO and DSO) are defined for each regulatory period (every 3 years), while the values of the incentives (rewards or penalties) are calculated on an annual basis.

While there is no quality scheme for TSOs in **Slovenia**, there is a scheme on the distribution levels, which uses a combination of rewards and penalties for continuity regulation. The scheme is fully flexible regarding the indicators used, the levels of penalties and rewards, quality classes, dead bands, etc. In general, the parameters and indicators are specified for one regulatory period. For the actual regulatory period, the indicators considered are SAIDI and SAIFI values, which are separated for rural and urban. The NRA performed 2 surveys to assess customer interruption costs (2007 and 2010). However, the utilisation of both studies in terms of design of the incentive scheme was limited. Furthermore, the NRA is currently working on the estimation of an optimal continuity level to update the incentive scheme for the next regulatory period. Within the scheme, there is a long-term reference (target) value for SAIDI and SAIFI in each regulatory period set. In addition, it is defined and applied separately for each distribution area in a particular area type (rural, urban). It is defined using the reference standards calculated each year applying the requested improvement on the initial (starting) level of continuity of supply using SAIDI and SAIFI. A minimum improvement of the continuity level is demanded according to the initial starting level: if the long term reference level has already been reached, there is no consequence; if it has not been reached, then an improvement is demanded on a yearly basis. The current scheme uses a dead band to avoid strong effects on the tariff (optimizing the administrative costs) caused by non-structural changes in level of continuity of supply (i.e. stochastic variations around the reference). The Slovenian incentive structure is partly linear and partly constant in a sense that a certain constant band (constant economic effect) is applied for each quality class and a linear function is defined in the range between the quality classes. This is introduced for the same reason as in case of so called dead-band: to avoid the effect on the tariff (optimizing the administrative costs) of non-structural changes in level of continuity of supply (i.e. stochastic variations around the reference of a certain class). Rewards and penalties are capped and also floored (to the certain percentage of controlled costs for O&M). Capping is applied since the NRA has not yet completely verified/validated the customer information on the marginal valuation of quality. The continuity scheme is linked to the regulatory formula, which corresponds to a mix of revenue and price-cap regulation and is funded by all customers via regulated tariffs.

7. See CIRED paper no 494 and CEER GGP C10-EQS-41-03 for further details.

Spain applies a scheme that uses rewards for TSOs and incentives for DSOs. While the availability of facilities is considered at the TSO level, the continuity indicators which are used for DSOs include TIEPI and NIEPI which are similar to ASIDI and ASIFI. While no cost estimation survey was conducted for TSOs, cost estimation was used within the reference network model to calibrate incentives when minimum continuity requirements were established for DSOs. However, no estimation of an optimal continuity level was conducted. For DSOs, the incentive is calculated separately for different areas. The scheme is based on target values, which are considering the average between specific DSO data indexes in each area in the previous 3 years, and national average data indexes in that area. The incentive scheme does neither involve a dead band nor a minimum improvement of the continuity level. Although the time scale is yearly, it considers previous quality values for establishing future targets. The incentives (rewards, penalties, others) are not proportional to the difference between the actual performance level and the standard (or target). The quality incentives vary between -3% and 3% of the distribution company's total remuneration.

Sweden uses a combination of rewards and penalties for the TSO as well as for the DSO level. While continuity indicators used for TSOs include ENS and PNS, ENS, PNS / SAIDI, SAIFI, CEMI4 are used for DSOs. The NRA conducted a cost estimation survey to set an incentive rate for the continuity of supply (CoS) indicators. By setting an incentive rate based on data from customer surveys ("bottom up"), the quality regulation aims to give to incentives for a socioeconomic level of CoS. An explicit Q-element is calculated using the mentioned CoS-indicators, whereby the target for DSOs (there is no target and no minimum improvement determined for TSOs) is set using a benchmarking method where DSOs with similar customer density are exposed to a similar target. The target is not an "optimal" level but the mean value of the relevant CoS indicators, i.e. it is calculated based on the mean value of all DSO CoS-indicators (per customer group) as a function of customer density. That target is predefined during the regulatory period and has to be reached within 4 years. Afterwards it is updated for the next period. The scheme does not involve the use of a dead band. Incentives are calculated as follows:

(1) $$Q_{TSO} = (ENS_{Target} - ENS_{result}) \times \cos t$$ (2) $$Q_{DSO} = (SAIDI_{Target} - SAIDI_{result}) / 60 \times P_{mean} \times \cos t$$

For both TSOs and DSOs, the scheme is linked to the overall revenue-cap model while quality incentives are capped with 5% of total (capped) revenues. The scheme is funded only by costumers of areas/companies which are entitled to incentives.

2.7.4. Regulation at single-user level and economic compensation

Various countries employ incentives on single-user level, as presented in Table 2.15. For historic evolution of incentive regimes please refer to Section 2.8.5 of the 5th Benchmarking Report on the quality of electricity supply [5].

Nearly two thirds of countries offer individual compensation to network users when standards are not met. Individual compensation is not in place in Austria, Croatia, Cyprus, Denmark, Germany, Latvia, Luxembourg, the Slovak republic and Switzerland. Greece has introduced compensation scheme since the 5th Benchmarking Report.

In most cases, economic compensation has to do with individual duration of long unplanned interruptions. How long a customer would have to be out of power depends not only on a country, but sometimes also on connected capacity, voltage level and even weather conditions. In this compensation scheme, the minimum duration of an interruption eligible for compensation varies between 1 hour (in the Netherlands, but this depends on capacity and voltage level, see Table 2.16) and 24 hours (in Ireland). Additionally, Estonia and Romania offer compensation for planned interruptions if they exceed certain threshold.

A different compensation scheme has to do with aggregated values in a year: total duration or total number of interruptions. Spain, Portugal and Slovenia employ both these programmes. In addition, Poland offers compensation for total duration of interruptions while Hungary reimburses customers if a total number of interruptions in a year exceeds a set limit. In Italy such a mechanism is applied for MV customers only in case of exceeding maximum number of short and long interruptions in a year.

Compensation is not received automatically in every country. Of 17 countries that remunerate customers if various interruption standards are not met, only 11 offer automatic compensation: Estonia, Finland, France (one standard), Great Britain (priority service register only), Greece, Hungary, Italy, the Netherlands, Portugal, Spain and Sweden. Even in these countries compensation is not automatic in every case. In France, automatic compensation applies to one standard while in Great Britain only customers on the priority service register receive automatic compensation. In most countries customers have to ask for reimbursement. In Norway, for example, system operators are obligated to annually inform their customers on how to request compensation and to have a standard request form available. In Slovenia, customers may issue the request for compensation for each calendar year by providing required data (own interruption register) to DSO. This means that customers should already have the appropriate measuring equipment installed.

When considering the minimum guaranteed standards, exceptional events are included except in the Czech Republic, Greece, Poland, Portugal, Slovenia and Sweden. Compensation per customer per year is limited in these countries: Bulgaria, Finland, Great Britain, Norway (only for cabins, for other customers there is no limit), Portugal, Romania, Slovenia and Spain.

TABLE 2.15 STANDARDS FOR WHICH ECONOMIC COMPENSATION APPLIES

Type of standard	Country adopting the standard	Standard value	Automatic compensation
Individual duration of long unplanned interruption	CZ, EE, EL (1), FI, FR, GB, HU, IE, LT, NL, NO, RO, SE	8h for the capital – Prague, 12h elsewhere (CZ) (2), >12h (EL), >6h (FR), >12h (FI), >12h (GB) (7), >24h (IE), >8 urban, >12 suburban and rural (IT), >12h, >1h (NL) (5), >12h (NO), >12h (SE)	EE, EL, FI, FR, GB (only customers on the priority service register), HU, NL, SE
Individual duration of long planned interruptions	RO, EE		EE
Total duration of long interruptions (planned or unplanned or both) in a year	ES, PL (3), PT (8), SI	45min<T<17h (PT) (6), >9h (SI) (4)	ES, PT
Total number of interruptions (long or short or both) in a year	ES, HU (short), IT (1) (long and short), PT (8), SI	6-9-10 long+short, according to territorial density (IT), 3<n<20 (PT)	ES, IT (1), PT
Single-user advance notice for planned interruptions	IE	2 days	

(1) Applies to MV customers only.
(2) Applies to LV.
(3) Poland differentiates between planned and unplanned interruptions.
(4) Individual customers (LV and MV).
(5) Depends on voltage level and capacity of the connected customer.
(6) EHV starts at 45 minutes.
(7) If a customer is without supply for 12 continuous hours under normal weather conditions, then they are eligible for a payment. If there is "severe weather" (determined by there being at least 8 times the daily average number of faults at HV (1 kV+) and above in a 24 hour period), then a customer must be without supply for at least 24 continuous hours.
(8) For comparison with standards, only long unplanned interruptions are considered.

The level of compensation can be set as a percentage of yearly network tariffs (the Czech Republic, Finland, Sweden), determined through customer research (Great Britain), based on international comparison (Hungary, Italy), on estimated costs of interruptions (the Netherlands, Portugal, Romania, Slovenia) or on the cost of energy during the period of interruption (Poland).

The following paragraphs offer more insight into the level and limits of reimbursement in several countries:

- In Bulgaria, customers experiencing no electricity supply for more than 24 hours receive compensation in the amount of 30 BGN with 20 BGN added for every subsequent period of 12 hours without electricity.

- In the Czech Republic, reimbursement is similarly set at 10 % of yearly payment for network tariffs and limited to €250 at low voltage, €500 at medium voltage and €5,000 at high voltage.

- In Finland, economic compensation is defined by Finnish Electricity Market Act and capped at €2,000. The rates are as follows: 10% of yearly network tariff for outages lasting 12-24h, 25% of yearly network tariff for outages lasting 24-72h, 50% of yearly network tariff for outages lasting 72-120h, 100% of yearly network tariff for outages lasting 120-192h, 150% of yearly network tariff for outages lasting 192-288h and 200% of yearly network tariff for outages lasting longer than 288h.

- France offers reimbursement to customers if single unplanned interruptions are longer than 6 hours (including exceptional events but excluding interruptions attributable to customers). The compensation from TSOs is 2% on the fixed part of the network tariff for every full 6-hour period of interruption. From DSOs, customers are entitled to 20% of the annual amount of the fixed part of tariff for interruptions longer than 6 hours and additional 20% for every additional 6-hour period. In other words, compensation for interruptions between 6 and 12 hours is 20% of the yearly fixed tariff, for interruptions between 12 and 18 hours it is 40% etc. Fixed part of the tariff is what is paid by customer for the connected power capacity. There are no differences according to type of customer except for DSOs which are customers of TSOs and can either choose the standard payment from TSOs (2% for 6 hours) or TSO's participation in the compensation payments to DSO's own customers. In case of exceptional events, the main distribution system operator ERDF has to re-energize more than 90% of its customers within 5 days.

- In Great Britain, where the compensation level has been set through customer research, rates differ for domestic and business customers and are capped at £700 per customer per year. Domestic customers are entitles to £75, while business customers receive £150 for the first 12 hours, then £35 for every 12th hour. This 12-hour standard applies under normal weather conditions. If the interruption was due to an exceptional event, then the customer must be without power for a minimum of 24 hours, or 48 hours for large events.

- Medium voltage customers in Greece are entitled to €150 if an interruption exceeds 12 hours.

- In Italy, automatic reimbursement applies for all customers involved in long interruptions. Threshold currently still depends upon territorial density but in 2016 a convergence process has been started at the end of which (2020) the same threshold will be applied (8 hours). The amount of automatic reimbursement for LV customers starts from €30 at the threshold level and increases by €15 every 4 hours up to a maximum of €300. Interruptions for exceptional events are also included in this protection scheme. For MV only, a further scheme is also applied. Customers on MV level suffering too many interruptions in a single year (considering both long and short ones) receive an automatic reimbursement provided that they are compliant with proper technical requirement for connection.

Compensation levels in the Netherlands distinguish between the voltage levels where the interruption was caused and between customers' connected capacity. These are presented in Table 2.16 in detail.

TABLE 2.16 COMPENSATION LEVELS IN THE NETHERLANDS

Type of standard	Interruption caused by a failure in the network with a voltage <= 1 kV	Interruption caused by a failure in the network with a voltage > 1 kV and < 35 kV	Interruption caused by a failure in the network with a voltage >= 35 kV
For each connection <= 3 x 25 A in a network with a voltage <= 1 kV	€35 for an interruption of 4 to 8 hours, plus €20 for each subsequent unbroken period of 4 hours	€35 for an interruption of 4 to 8 hours, plus €20 for each subsequent unbroken period of 4 hours	€35 for an interruption of 4 to 8 hours, plus €20 for each subsequent unbroken period of 4 hours
For each connection > 3 x 25 A in a network with a voltage <= 1 kV	€195 for an interruption of 4 to 8 hours, plus €100 for each subsequent unbroken period of 4 hours	€195 for an interruption of 2 to 8 hours, plus €100 for each subsequent unbroken period of 4 hours	€195 for an interruption of 1 to 8 hours, plus €100 for each subsequent unbroken period of 4 hours
For each connection in a network with a voltage > 1 kV and < 35 kV		€910 for an interruption of 2 to 8 hours, plus €500 for each subsequent unbroken period of 4 hours	€910 for an interruption of 1 to 8 hours, plus €500 for each subsequent unbroken period of 4 hours
For each connection in a network with a voltage > 35 kV			€0.35 per contracted kW for an interruption of 1 to 8 hours, plus €0.20 per contracted kW for each subsequent unbroken period of 4 hours

Compensation levels are based on estimated customer costs caused by interruptions. A customer survey to establish costs of interruptions for households and small business customers was conducted in 2004. An update of this study from 2009 is currently used as a basis for quality regulation. Payments to customers are not required if the interruption of the transmission service is the result of automatic or manual load shedding, if the network operator can demonstrate that due to an extreme situation it was unable to repair an interruption within the restoration times or if an interruption is caused in HV or EHV networks.

In Norway, the NRA sets the compensation level but does not differentiate according to the type of customer. All conditions are eligible as long as the power outage is at least 12 hours long. The amounts are: NOK 600 for interruptions between 12 and 24 hours, NOK 1,400 for interruptions between 24 and 48 hours and NOK 2,700 for interruptions between 48 and 72 hours. For interruptions longer than 72 hours, the compensation is NOK 1,300 per each 24- hour period. The only differentiation for customers applies to cabins, for which a cap is set at the expected value for the annual grid tariff. There is no cap for other customers. In addition, customers having more than one connection point are not entitled to more than one compensation for one interruption.

The levels of compensation in Portugal are defined by the concept of the Value of Lost Load. A limit of 100% of customer's annual network tariff (for the previous year) was defined as a result of benchmarking with other European countries and was introduced in 2014. Before 2014, the total amount of compensation was limited to 10% of the annual energy bill of a consumer. Since the standards are differentiated by voltage level and geographic area, the compensation level is also differentiated by these 2 characteristics.

Slovenia sets their level of compensation according to result of an internal assessment of industrial customer interruption costs. The compensation for industrial customers (MV level) is determined by the connected load (≤250 kW or >250 kW) as well as the extent of a breach of particular standard (duration or number of interruptions).

Compensations are also available for individual customers on low or medium voltage level who suffered extremely long interruptions: more than 9 hours due to planned or unplanned interruptions (excluding exceptional events and third party responsibility) or more than 18 hours due to unplanned interruptions for which only the DSO is responsible.

In Sweden, for an outage period between 12 and 24 hours, compensation is set as 12.5% of consumer's estimated annual network cost. For outages longer than 24 hours, further compensation of 25% of consumer's annual cost shall be paid for each 24h period commenced thereafter. For one outage period, compensation is limited to 300% of consumer's annual network cost. However, electricity consumers are not entitled to compensation for outages if the outage is attributable to a fault in a cable network with voltage of 200 kV or above, if the outage is customer's fault or if the transmission of electrical power is discontinued in order to take measures to maintain good operational or supply security and the outage does not last longer than the measure requires.

In addition to compensations for failing to meet standards, there exist also schemes in Ireland and Great Britain for worst-served customers. In Great Britain, while not considered a specific regulation or standard, funding is available for DNOs who are trying to improve the performance experience for those customers meeting the criteria for being considered worst-served. Funding is available at a rate of £1,000 per customer per scheme. In Ireland, the NRA has made an allowance of 2 million Euro per year within the DSO revenue, which the DSO can use to improve services to worst-served customers. The details of this scheme have not been finalised yet. Similar allowances for TSOs are not in use.

2.8. FINDINGS AND RECOMMENDATIONS ON ELECTRICITY CONTINUITY OF SUPPLY

Finding 1
Continuity of supply is monitored in all responding countries.

All countries that participated in CEER's survey stated that they monitor continuity of supply in their electricity networks. In addition, most ECRB countries that were featured in the ECRB Annex of this Report monitor continuity of supply. So do Israel and Algeria that provided input for case studies.

The monitoring usually covers long interruptions (see Table 2.2 for definitions of duration) and differentiates between planned and unplanned outages. Short interruptions are monitored by a minority of countries.

About two thirds of responding countries keep track of interruptions on all voltage levels. Those that do not, usually omit what they consider low or extra high voltage. It should be kept in mind that voltage level definitions are not standardised.

Finding 2
Continuity of supply indicators and procedures for data collection and analysis vary across countries.

Diverse indicators and weighting methods are employed when evaluating interruptions in various countries. The use of multiple indicators enables the collection of more information and offers more possibilities to observe trends. The most commonly used indicators are SAIDI and SAIFI with most countries using weighting by the number of users. Many countries that monitor short interruptions keep track of the yearly number of those interruptions and use MAIFI or MAIFIE as indicators. Even the use of the same indicator does not guarantee easy comparison. For example, aggregation rules for counting short interruption sequences vary across Europe and can greatly affect the values of an indicator, in this case MAIFIE. Indicators such as ENS and AIT are frequently used to monitor continuity of supply in transmission networks. Certain indicators are presented with and without exceptional events with countries having their own interpretation of what constitutes an exceptional event.

The level of detail being monitored is not harmonised either (as presented in Table 2.6 and Table 2.7). Most countries collect some information on the cause of interruptions. If collected in detail, this provides NRAs with important information and can be used as an essential part of the improvement of continuity of supply.

Finding 3
Calculation of continuity of supply indicators varies across countries.

As already mentioned above, various continuity of supply indicators are used across countries. It can be assumed from the obtained data that even in case of using the same indicators (e.g. SAIFI, SAIDI), different approach to calculating these parameters exists. One of the differences, for example, is including or excluding each specific cause of interruption (force majeure, exceptional events etc.). Concurrently, each country can have different approach to calculation of complicated causes where lots of sequences of interruptions with different duration (long or short) and different numbers of affected customers occur. The same approach in each country and the whole EU is a basic assumption for a correct evaluation and comparison.

Finding 4
There is a different approach to exceptional events across countries.

Based on the data analysis, it is obvious that the share of exceptional events has serious impact on the values of continuity of supply indicators. Table A.13 in Annex A illustrates the different definitions and approaches to exceptional events. One of the reasons for the difference could be that lots of countries defined exceptional events with respect to their historical experiences or geographic reasons. Some countries have no definition in place. As a result, it is not clear what types of interruptions are considered in exceptional events. Therefore, the comparison of continuity of supply indicators among European countries must take into account this diversity in the definitions of exceptional events.

Finding 5
Incentive schemes are used to regulate continuity of supply in distribution and transmission networks.

General reward or penalty schemes or incentives to optimise the continuity of supply on a system level are applied in more than half of the countries that responded. A total of 3 new countries have introduced incentive schemes since the last report was published.

Most countries use a combination of rewards and penalties in both distribution and transmission while several countries have regimes that focus exclusively on penalties (Denmark, Hungary) or rewards (Belgium, Spain). Austria, Greece, Luxembourg and Romania are considering implementing a regulation of continuity of supply on system level. The incentive schemes are often based on benchmarking or on network operator's historical level of actual continuity of supply.

Finding 6
Incentive schemes for individual continuity levels are used in many countries and have different formulations.

Compensation schemes at single-user level are applied in more than half of the countries. The schemes mostly correspond to reimbursement of customers based on duration of individual long interruptions (planned or unplanned), although total duration and total number of interruptions in a year are also used. The minimum outage duration necessary for compensation vary from 1 to 24 hours. This, as well as the level of compensation, differs not only by country but also by voltage level, connected capacity, type of customer (business or domestic) and even weather conditions. In most countries, exceptional events are included when considering the minimum guaranteed standards.

The level of compensation can be set as a percentage of yearly network tariffs (the Czech Republic, Finland, Sweden), determined through customer research (Great Britain), based on international comparison (Hungary, Italy), on estimated costs of interruptions (the Netherlands, Portugal, Romania, Slovenia) or on the cost of energy during the period of interruption (Poland).

RECOMMENDATION 1

EXPAND THE MONITORING OF CONTINUITY OF SUPPLY.

It is recommended to include incidents at all voltage levels in interruption statistics in all responding countries. Moreover, monitoring of short interruptions should be extended to those countries that currently monitor only long interruptions. Monitoring of transient interruptions could be introduced in as many countries as possible. A decision at national level is needed on automatic methods for determining the duration and number of affected users for incidents at LV. The costs of such a scheme should be considered in that decision.

RECOMMENDATION 2

HARMONISE CONTINUITY OF SUPPLY INDICATORS AND DATA COLLECTING PROCEDURES.

In order to enable easier comparison and benchmarking between countries, CEER recommends standardisation of data collecting procedures with a single scheme tied to the duration and frequency of long interruptions (SAIDI and SAIFI), the frequency of short interruptions (MAIFIE) and to ENS due to interruptions in transmission networks. Common rules for aggregation of short interruptions should be investigated and pursued by CEER, before more countries begin to use short interruption indicators. Common weighting methods should also be employed for easier comparison of indicators between countries.

CEER confirms its recommendation that any publication of continuity of supply data should include information on the interruptions that are excluded and included.

RECOMMENDATION 3

HARMONISE CALCULATION OF CONTINUITY OF SUPPLY INDICATORS.

In order to have comparable data, CEER recommends harmonising the methods of calculation such as aggregation rules and weighting of the continuity of supply indicators in use. In connection with this recommendation, there is a case study in Section 2.9.2 as an example of calculation of continuity indicators SAIDI and SAIFI with focus on complicated causes that usually happen in practice. At the same time it is very important to mention that the uniformity of this methodology is significantly important mainly for grid operators (TSO and DSO) which log all details of each specific event or calculate the indicators.

RECOMMENDATION 4

ESTABLISH AND HARMONISE DEFINITION OF EXCEPTIONAL EVENTS.

CEER recommends establishing the definition of exceptional events in each country. Concurrently, it is also important to harmonise these definitions at the EU level in order to achieve comparable data. The characterisation of exceptional events is also essential for unbiased evaluation of continuity of supply indicators because it is assumed that extreme events, which would distort statistics, will be excluded. At the same time, this definition should eliminate the grid operators' responsibility, because they do not have any possibility to influence exceptional events.

RECOMMENDATION 5

IMPLEMENT AN INCENTIVE SCHEME FOR MAINTAINING OR IMPROVING GENERAL CONTINUITY LEVELS.

CEER recommends that NRAs implement adequate incentive schemes in order to maintain continuity of supply levels or improve them, if economically viable on both the distribution and the transmission levels.

CEER confirms its past recommendation that the results from cost-estimation studies on customer costs due to electricity interruptions are of key importance in order to be able to set proper incentives for continuity of supply.

RECOMMENDATION 6

IMPLEMENT COMPENSATION PAYMENTS FOR NETWORK USERS AFFECTED BY VERY LONG INTERRUPTIONS.

CEER recommends that the monitoring of interruptions is extended to a customer survey at single-user level to provide the basis for individual compensation schemes.

CEER recommends the standardisation of payments among the European countries. However, compensation payments should depend on the respective connection level.

2.9. CASE STUDIES

2.9.1. Case study: Incentive-based regulation of the quality of electricity supply in the Czech Republic

The following part describes the historical development of the regulation of the quality of electricity supply in the Czech Republic. The description is set out in the frame of "regulatory periods", i.e. predefined periods of time in which the principle of regulation in place is kept unchanging, with only certain parameters adjusted year-to-year.

In 2001, the Energy Regulatory Office (ERO) promulgated its first public notice [i.e. statutory instrument] on the quality of electricity supply. It specified the basic standards of the quality of electricity supply and related services. However, this public notice did not contain any repressive measures on the part of the NRA, which would have permitted to penalise the breach of the standards. Due to the insufficient empowerment in the Energy Act, the issue of the quality of electricity supply was not addressed any further during the first regulatory period (2002-2004).

In the second regulatory period (2005-2009), ERO promulgated a new public notice, number 540/2005 on the quality of electricity supply and related services in the electricity industry, which introduced standards defining levels of quality that had to be kept in each individual case, i.e., it laid down the minimum level of quality for each of the customers. It also laid down the amounts of compensation for breach of the required standards, the time limits for claiming such compensation, and the procedures for reporting on the keeping of the quality of supply and services. No other requirements for quality were introduced in the second regulatory period.

During the third regulatory period (2010-2015), incentive-based quality regulation was introduced in the Czech Republic; its purpose was to set the required level of the quality of provided services in relation to the price of the services. The purpose of this mechanism was to improve the quality of electricity supply throughout the system, or in each of the distribution systems, unlike the quality public notice that had primarily focused on each individual customer. The formula for calculating allowed revenues was extended to include a term adjusting the value of allowed revenues by a penalty or bonus for the quality level achieved. At the beginning of the third regulatory period, a sufficiently long time series of continuity indicators was not available in the Czech Republic, and the incentive-based quality regulation was therefore only implemented in practice as of 2013.

For the fourth regulatory period (2016-2018), ERO maintains in place a combination of the above mentioned regulatory mechanisms, i.e. the public notice (standards) and incentive-based regulation. In the case of incentive-based quality regulation there is a difference compared with the preceding regulatory period, in that some new features have been introduced on the basis of the experience gained with the implementation of incentive-based regulation. The purpose is a gradual improvement in the quality of electricity supply, specifically reductions in the number and duration of long interruptions in electricity distribution, both unplanned and planned ones. More details about the mechanism of incentive-based quality regulation for the fourth regulatory period are contained in the following text.

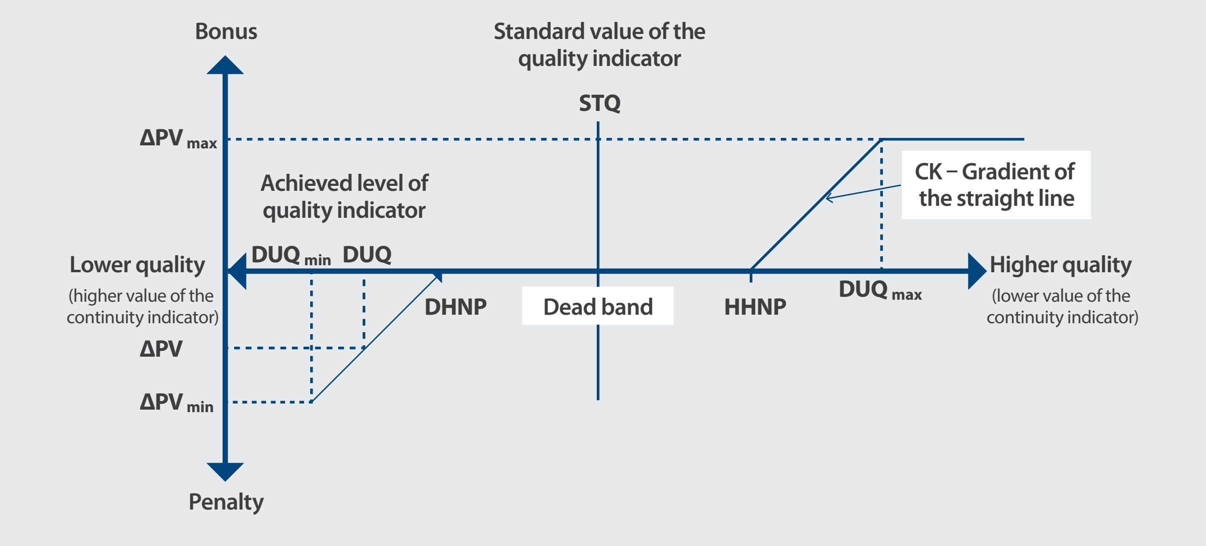
Mechanism of incentive-based quality regulation in the Czech Republic

The Czech Republic's incentive-based quality regulation applies only to electricity distribution. In the Czech Republic, only one company provides electricity transmission and ERO does not regard the quality of electricity in the transmission system problematic, because only a few interruptions per year occur. Electricity transmission is therefore presently not subject to incentive-based regulation.

The quality of network services in distribution is evaluated using a combination of SAIFI and SAIDI (continuity indicators). The calculation of the continuity indicators is set out in quality public notice number 540/2005.

Individual parameters of the quality indicator are set for each of the regional distribution system operators. The required values of SAIFIQ and SAIDIQ are "whole-system" indices, i.e. indices for the respective system operator's entire distribution system without differentiating between voltage levels. The amount of the penalty or bonus for the quality level achieved in electricity distribution is calculated on the basis of the achieved values of the continuity indicators in electricity distribution as against the required values set by the ERO. Together with the required quality parameters, upper and lower limits are set, beyond which the maximum value of the bonus or penalty are applied. A "dead band" is also used, within which no bonuses or penalties are applied. This feature helps to partly eliminate the probable year-to-year fluctuations in the achieved values of continuity indicators. The mechanism of incentive-based quality regulation is shown in the following diagram.

FIGURE 2.21 INCENTIVE-BASED QUALITY REGULATION DIAGRAM



Where:

ΔPV_t	bonus/penalty for the quality achieved, expressed in financial terms
t	order number of the regulated year
DUQ	the achieved value of the quality indicator in the period relevant for assessing service quality for the respective year of the regulatory period
CK	unit price of quality
ΔPV_{max}	maximum bonus for service quality achieved
ΔPV_{min}	maximum penalty for service quality achieved
DHNP	lower limit of the dead band
HHNP	upper limit of the dead band
STQ	the required value of the quality indicator ($SAIDI_Q$ and $SAIFI_Q$)
DUQ_{max}	limit value of the quality indicator, from which the maximum bonus for achieved service quality is applied
DUQ_{min}	limit value of the quality indicator, from which the maximum penalty for achieved service quality is applied

New features of incentive-based quality regulation for the fourth regulatory period

1 Clear-cut definition of the input indicators:

Incentive-based quality regulation only includes such events in the calculation of $SAIFI_Q$ and $SAIDI_Q$, which are within the system operator's control. This principle was also applied in the third regulatory period but it was not set out in the relevant methodology. Due to this fact, the calculation of continuity indicators includes only the following interruption categories under Annex 4 to public notice number 540/2005:

- Unplanned failure-related interruptions in electricity distribution caused by failures originating in the installations of the system operator's distribution system or in the operation thereof under usual weather conditions; and
- Planned interruptions in electricity distribution.

On the other hand, the following interruption categories are not included in the calculation of $SAIFI_Q$ and $SAIDI_Q$:

- Unplanned failure-related interruptions in electricity distribution caused by failures originating in the installations of the system operator's distribution system or in the operation thereof under unfavourable weather conditions;
- Unplanned failure-related interruptions in electricity distribution caused by third-party interference or action;
- Forced unplanned interruptions in electricity distribution (during imminent danger of one's life, health or property and during liquidation of these states);
- Extraordinary unplanned interruptions in electricity distribution (during emergency states or prevention of emergency states); and
- Unplanned interruptions in electricity distribution caused by events outside the system operator's system and at the generator.

2 Setting the required values for the whole regulatory period:

Since the development and extensive refurbishments of distribution systems are time and cost intensive activities that have to be planned for a long time in advance, setting the required targets for a longer period of time, i.e. determining the achievable level of the quality of electricity supply is necessary for incentive-based quality regulation to work. This step makes it possible for the particular companies to make, well in advance, the necessary preparations for implementing the measures that will help to improve electricity supply quality parameters. For this reason, the required values of $SAIFI_Q$ and $SAIDI_Q$ are set for the whole regulatory period. In the third regulatory period, the required values were set every year.

A new feature is the fact that for the fourth regulatory period, the required values of continuity indicators have been set on the basis of an analysis of the relationship between the possible measures for reducing continuity indicators and the costs spent by the particular distribution system operators. The purpose of this analysis was to identify the relationship between costs and quality on an individual basis for each of the distribution system operators. Specifically, it was based on the calculation (simulation) of reliability using real data for selected distribution network feeders. The principle of the analysis is described in a paper delivered at the CIRED 2015 conference in Lyon (Paper 1078).

3 Implementing a two-year moving average:

Another new feature implemented beginning the fourth regulatory period is the two-year moving average. The feature has been introduced in order to smooth out the year-to-year changes in continuity indicators even more. Values of $SAIFI_Q$ and $SAIDI_Q$ for individual years will no longer enter the calculation of the quality factor Q; their average values for the last 2 years will be used instead.

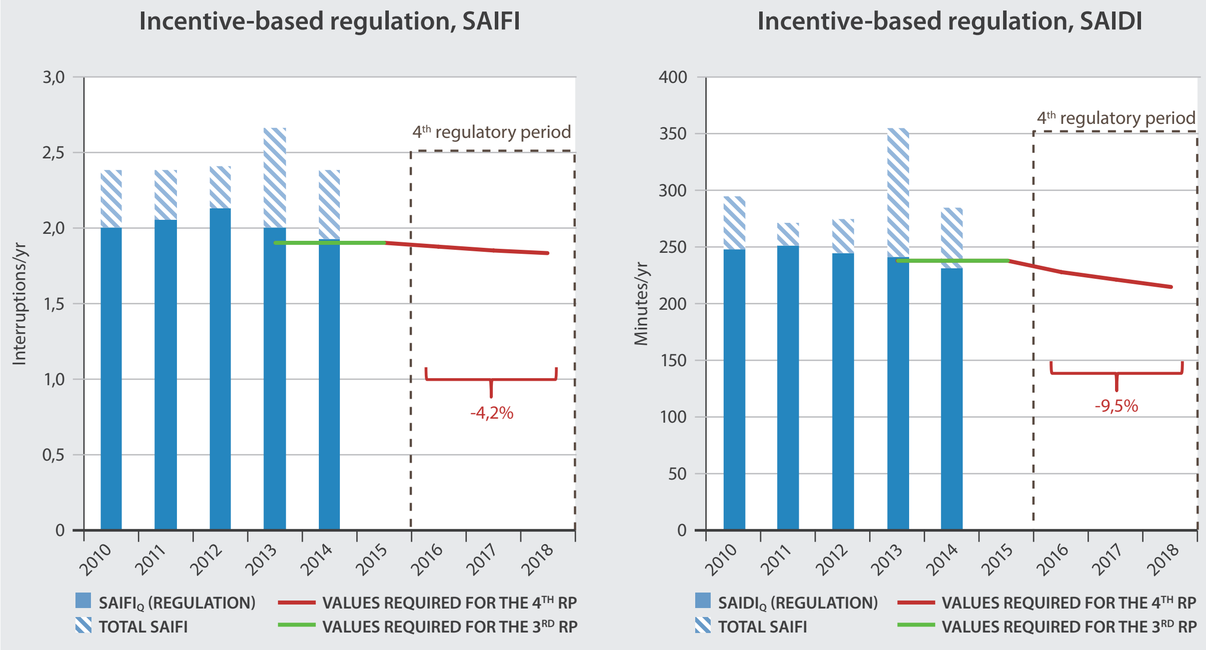
When two-year moving averages are used, attention must be paid to the way of setting the required values of continuity indicators. Should the year-to-year tightening of the indices (in percentage terms) be higher than half of the dead band (the band within which the bonus and penalty are zero) the principle of moving average would work as another tightening feature. This undesirable effect might cause considerable complications for the utilities in achieving the required values.

Quality indicator parameters set for the fourth regulatory period

The purpose of incentive-based quality regulation is to provide sufficient incentives to distribution system operators to improve the quality of electricity supply for final customers. For the fourth regulatory period, the ERO also wanted to accentuate quality within the entire regulatory mechanism. The ERO has therefore increased the maximum amount of the bonuses/penalties from ±3% (in the third regulatory period) to ±4% of the utility's profit. The limits of the dead band have been set as in the preceding years, i.e. at ±5% of the required value, and the value of the maximum bonus/penalty has been set at ±15% of the required value. In the case of the distribution company that operates the system in the country's capital (Prague), different values have been set (±10% and ±25% respectively) due to the different nature of its networks compared with other utilities in the Czech Republic (a small number of interruptions with heavy impacts on overall indicators).

The specific required values of $SAIFI_Q$ and $SAIDI_Q$ (STQ) have been set individually for each distribution company on the basis of an analysis of the relationship between quality and costs that was made for each company. The following charts show the reflection of required values of $SAIFI_Q$ and $SAIDI_Q$ for each of the distribution company on the level of the whole Czech Republic for the 3rd and 4th regulatory periods (calculation is made on the basis of the STQ values and the number of customers of each distribution company).

FIGURE 2.22 REQUIRED VALUES OF CONTINUITY INDICATORS



2.9.2. Case study: Examples of calculation of SAIFI, SAIDI continuity indicators in distribution systems in the Czech Republic

The following chapter provides examples of calculation of basic continuity indicators (SAIFI, SAIDI) in distribution systems, as it became apparent that the approach to continuity indicators calculation might be different in individual countries. Simultaneously, it is important to realise that different approach (or perception) may occur even among individual operators of distribution systems who are responsible (in many countries) for calculation of indicators or for reporting data necessary for such calculation. Nevertheless, the unification calculation method is the key prerequisite for further analyses or for comparison of individual companies or states. For these reasons this chapter intends to present instruction for calculation of basic continuity indicators (SAIFI, SAIDI) on the selected model example.

Model example of calculation

The presented example describes the procedure for calculation of the SAIDI, SAIFI indicators in more complicated cases where the operation steps during failure localisation usually interrupt electricity distribution to different groups of customers in the system for the period exceeding 3 minutes. At the same time, we have to emphasise that the example aims to facilitate unified understanding of indicators calculation and is not intended as a means for comparing advantages brought by different types of switching elements.

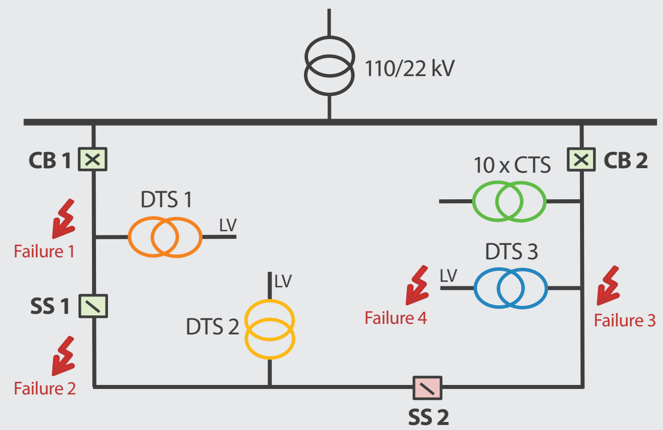
The model example encompasses 4 different failures in different parts of a distribution system. To allow for presenting calculation of not only the system indicators but also the voltage level indicators, the customers are connected to the LV – low voltage and MV – medium voltage levels. At the same time, the stated transformer stations (TS) are not interconnected on the LV side, hence the substitute feeding cannot be provided through operation on the LV level (utilised mainly in urban cable networks).

The example is provided for 2 alternatives of switching elements in the line (section switch and remotely controlled section switch). It is presumed that the first dispatcher's operation could not be executed in less than 3 minutes, regardless of the switching element type. We anticipate that the operations done by dispatcher in order to reconfigure the system into the pre-failure state would be finalised within 3 minutes, as in such case the dispatcher is ready for these operation steps and can carry them out in immediate sequence. Although in real operation the remotely controlled section switches can be used for operation also when the line is energised the operations within the example are considered only for no voltage state, i.e. after the feeder circuit-breaker was switched off.

To illustrate this point, individual alternatives are supplemented with graphical courses of interruption evaluation, including the method for detecting the failure location. Only the long- term interruptions, i.e. with the duration exceeding 3 minutes are used for calculation of the SAIFI, SAIDI indicators. The hatched areas of these courses are not included into the calculation, as their duration is shorter or equal to 3 minutes. Such interruptions would be potentially used for calculation of indicators that evaluate short-term interruptions (e.g. MAIFI), where the way of calculation applied would be similar to the one for SAIFI indicator.

Alternative with section switch (SS)

FIGURE 2.23 DISTRIBUTION SYSTEM DIAGRAM



Distribution transformer station (DTS)
Customer transformer station (CTS)

DTS 1 = 150 customers at LV
DTS 2 = 50 customers at LV
DTS 3 = 100 customers at LV
10 x CTS = 10 customers at MV

$N_{SLV} = 150 + 50 + 100 = 300$
$N_{SMV} = 10$
$N_S = N_{SLV} + N_{SMV} = 310$

CB – power circuit-breaker
SS – section switch

Switched on
Switched off

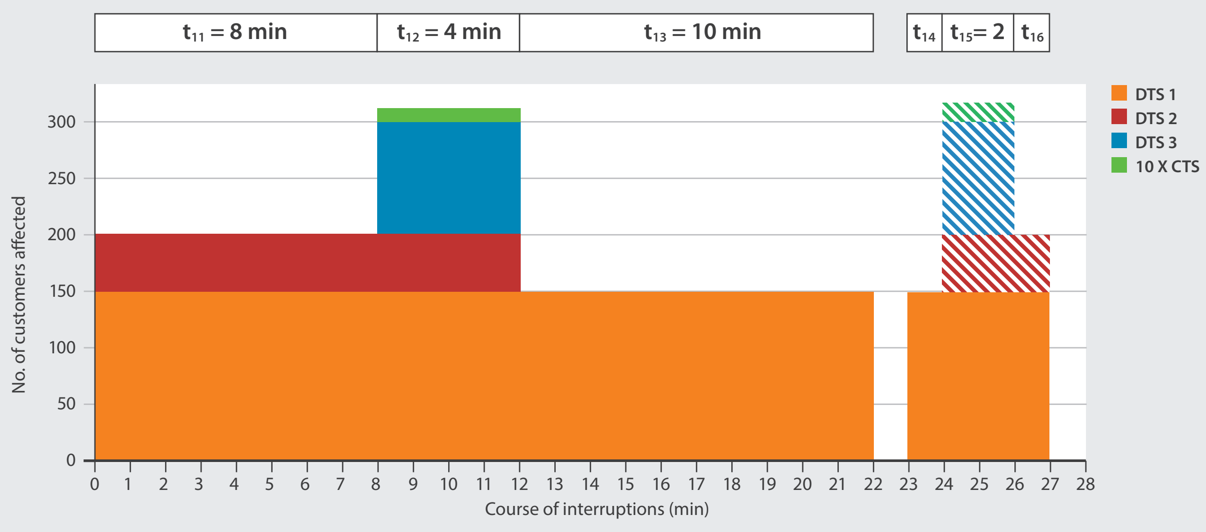
Failure 1

Course of operations in case of failure 1

TABLE 2.17 COURSE OF OPERATIONS IN CASE OF FAILURE 1

Process	Time elapsed from failure (min)
Triggering the CB 1 protection	t = 0
Switching off the SS 1, switching on the CB 1, triggering the CB 1 protection – detecting the location of failure	t = 6
Switching off the CB 2, switching on SS 2	t = 8
Switching on the CB 2 – partial restoration of supply	t = 12
Switching on the CB 1 – failure reparation finished	t = 22
Switching off the CB 1 – operations in order to reconfigure the system into the pre-failure state	t = 23
Switching off the CB 2, switching off the SS 2, switching on the SS 1	t = 24
Switching on the CB 2	t = 26
Switching on the CB 1	t = 27

FIGURE 2.24 GRAPHIC COURSE OF INTERRUPTIONS IN CASE OF FAILURE 1



Calculation of indicators

System indicators

$$SAIFI_S = \frac{\sum_{h=(LV,MV,...)} \sum_{j} n_{jh}}{N_S} = \frac{n_{1LV} + n_{1MV}}{N_S} = \frac{(150+50+100)+(10)}{310} = 1 \; [1/year]$$

$$SAIDI_S = \frac{\sum_{h=(LV,MV,...)} \sum_{j} t_{sj}}{N_S} = \frac{\sum_{h=(LV,MV,...)} \sum_{j} \sum_{i} t_{ji} \cdot n_{jhi}}{N_S} = \frac{t_{s1LV} + t_{s1MV}}{N_S} =$$

$$= \frac{(t_{11}.n_{1LV1} + t_{12}.n_{1LV2} + t_{13}.n_{1LV3} + t_{14}.n_{1LV4} + t_{15}.n_{1LV5} + t_{16}.n_{1LV6}) + (t_{12}.n_{1MV2})}{N_S} =$$

$$= \frac{[8 \cdot (150+50)+4 \cdot (150+50+100)+10 \cdot 150+1 \cdot 150+2 \cdot 150+1 \cdot 150]+[4 \cdot 10]}{310} = 15.94 \; [min/year]$$

Where:

- *h* indicates the voltage level (low voltage = LV, medium voltage = MV,…),
- *j* indicates the event (failure),
- n_{jh} is the total number of customers directly fed from the voltage level *h*, who were affected by interruption of electricity distribution as a result of the *j* event,
- t_{sj} is the total duration of all electricity distribution interruptions resulting from the *j* event at individual customers directly fed from the voltage level *h*, for whom the electricity distribution was interrupted,
- t_{ji} is the duration of the *i* operation step within the *j* event,
- n_{jhi} is the number of customers directly fed from the voltage *h*, who were affected by interruption of the electricity distribution in the given category in the *i* operation step of the *j* event,
- *i* is the sequence number of the operation step within the *j* event.

Voltage level indicators

$$SAIFI_{LV} = \frac{\sum_j n_{jLV}}{N_{SLV}} = \frac{n_{1LV}}{N_{SLV}} = \frac{(150+50+100)}{300} = 1 \ [1/\text{year}]$$

$$SAIDI_{LV} = \frac{\sum_j t_{sj}}{N_{SLV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jLVi}}{N_{SLV}} = \frac{t_{s1LV}}{N_{SLV}} = \frac{(t_{11}.n_{1LV1} + t_{12}.n_{1LV2} + t_{13}.n_{1LV3} + t_{14}.n_{1LV4} + t_{15}.n_{1LV5} + t_{16}.n_{1LV6})}{N_{SLV}} =$$

$$= \frac{8 \cdot (150+50) + 4 \cdot (150+50+100) + 10 \cdot 150 + 1 \cdot 150 + 2 \cdot 150 + 1 \cdot 150}{300} = 16.33 \ [\text{min/year}]$$

$$SAIFI_{MV} = \frac{\sum_j n_{jMV}}{N_{SMV}} = \frac{n_{1MV}}{N_{SMV}} = \frac{10}{10} = 1 \ [1/\text{year}]$$

$$SAIDI_{MV} = \frac{\sum_j t_{sj}}{N_{SMV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jMVi}}{N_{SMV}} = \frac{t_{s1MV}}{N_{SMV}} = \frac{t_{12}.n_{1MV2}}{N_{SMV}} = \frac{4 \cdot 10}{10} = 4 \ [\text{min/year}]$$

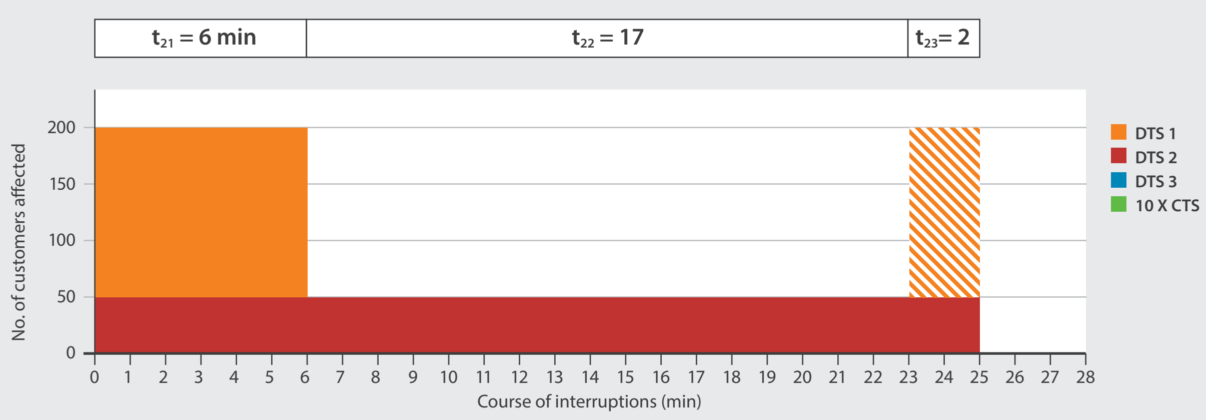
Failure 2

Course of operations in case of failure 2

TABLE 2.18 COURSE OF OPERATIONS IN CASE OF FAILURE 2

Process	Time elapsed from failure (min)
Triggering the CB 1 protection	t = 0
Switching off SS 1, switching on CB 1 – **detecting the location of failure**	t = 6
Switching off CB 1, switching on SS 1 – **operations in order to reconfigure the system into the pre-failure state**	t = 23
Switching on the CB 1	t = 25

FIGURE 2.25 GRAPHIC COURSE OF INTERRUPTIONS IN CASE OF FAILURE 2



Calculation of indicators

System indicators

$$SAIFI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j n_{jh}}{N_S} = \frac{n_{2LV}}{N_S} = \frac{150+50}{310} = 0.65 \ [1/year]$$

$$SAIDI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j t_{sj}}{N_S} = \frac{\sum_{h=(LV,MV,...)} \sum_j \sum_i t_{ji} \cdot n_{jhi}}{N_S} = \frac{t_{s2LV}}{N_S} = \frac{t_{21}.n_{2LV1} + t_{22}.n_{2LV2} + t_{23}.n_{2LV3}}{N_S} =$$

$$= \frac{6 \cdot (150+50) + 17 \cdot 50 + 2 \cdot 50}{310} = 6.94 \ [min/year]$$

Voltage level indicators

$$SAIFI_{LV} = \frac{\sum_j n_{jLV}}{N_{SLV}} = \frac{n_{2LV}}{N_{SLV}} = \frac{150+50}{300} = 0.67 \ [1/year]$$

$$SAIDI_{LV} = \frac{\sum_j t_{sj}}{N_{SLV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jLVi}}{N_{SLV}} = \frac{t_{s2LV}}{N_{SLV}} = \frac{t_{21}.n_{2LV1} + t_{22}.n_{2LV2} + t_{23}.n_{2LV3}}{N_{SLV}} =$$

$$= \frac{6 \cdot (150+50) + 17 \cdot 50 + 2 \cdot 50}{300} = 7.17 \ [min/year]$$

Failure 3

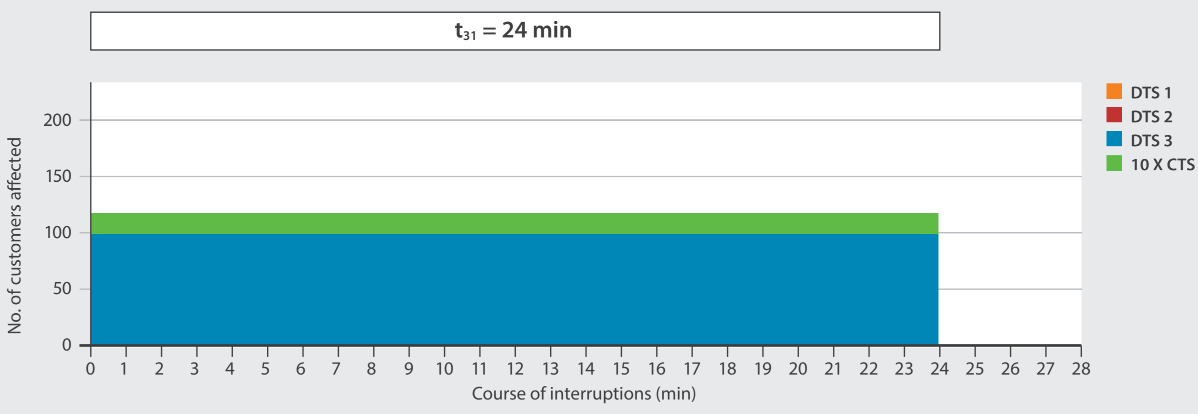
Course of operations in case of failure 3

TABLE 2.19 COURSE OF OPERATIONS IN CASE OF FAILURE 3

Process	Time elapsed from failure (min)
Triggering the CB 2 protection	t = 0
Switching on CB 2 – **failure reparation finished**	t = 24

Graphic course of interruptions in case of failure 3

FIGURE 2.26 GRAPHIC COURSE OF INTERRUPTIONS IN CASE OF FAILURE 3



Calculation of indicators

System indicators

$$SAIFI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j n_{jh}}{N_S} = \frac{n_{3LV} + n_{3MV}}{N_S} = \frac{100+10}{310} = 0.35 \ [1/\text{year}]$$

$$SAIDI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j t_{sj}}{N_S} = \frac{\sum_{h=(LV,MV,...)} \sum_j \sum_i t_{ji} \cdot n_{jhi}}{N_S} = \frac{t_{s3LV} + t_{s3MV}}{N_S} = \frac{t_{31} \cdot n_{3LV1} + t_{31} \cdot n_{3MV1}}{N_S} =$$

$$= \frac{24 \cdot 100 + 24 \cdot 10}{310} = 8.52 \ [\text{min/year}]$$

Voltage level indicators

$$SAIFI_{LV} = \frac{\sum_j n_{jLV}}{N_{SLV}} = \frac{n_{3LV}}{N_{SLV}} = \frac{100}{300} = 0.33 \ [1/\text{year}]$$

$$SAIDI_{LV} = \frac{\sum_j t_{sj}}{N_{SLV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jLVi}}{N_{SLV}} = \frac{t_{s3LV}}{N_{SLV}} = \frac{t_{31} \cdot n_{3LV1}}{N_{SLV}} = \frac{24 \cdot 100}{300} = 8 \ [\text{min/year}]$$

$$SAIFI_{MV} = \frac{\sum_j n_{jMV}}{N_{SMV}} = \frac{n_{3MV}}{N_{SMV}} = \frac{10}{10} = 1 \ [1/\text{year}]$$

$$SAIDI_{MV} = \frac{\sum_j t_{sj}}{N_{SMV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jMVi}}{N_{SMV}} = \frac{t_{s3MV}}{N_{SMV}} = \frac{t_{31} \cdot n_{3MV1}}{N_{SMV}} = \frac{24 \cdot 10}{10} = 24 \ [\text{min/year}]$$

Failure 4

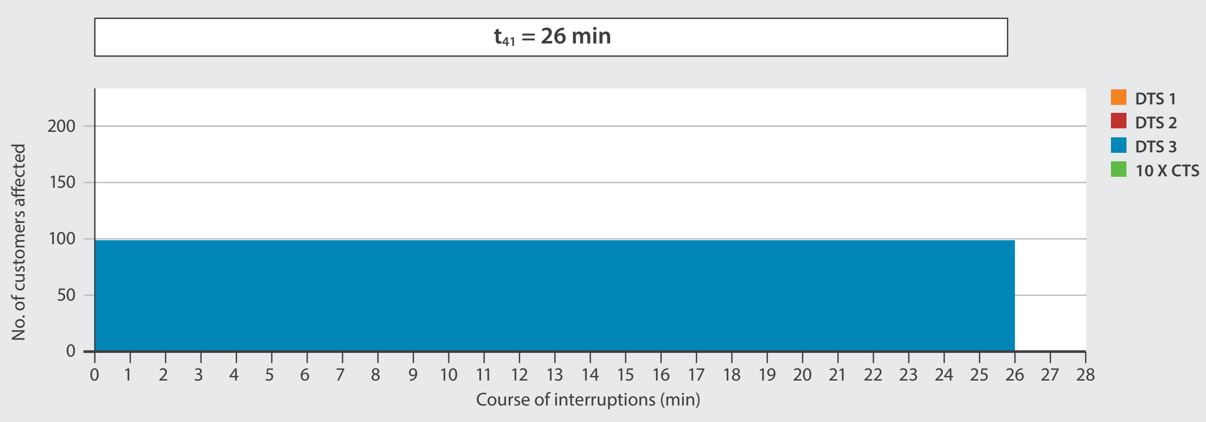
Course of operations in case of failure 4

TABLE 2.20 COURSE OF OPERATIONS IN CASE OF FAILURE 4

Process	Time elapsed from failure (min)
Triggering the DTS 3 protection	t = 0
Switching on the DTS 3 – **failure reparation finished**	t = 26

Graphic course of interruptions in case of failure 4

FIGURE 2.27 GRAPHIC COURSE OF INTERRUPTIONS IN CASE OF FAILURE 4



Calculation of indicators

System indicators

$$SAIFI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j n_{jh}}{N_S} = \frac{n_{4LV}}{N_S} = \frac{100}{310} = 0.32 \; [1/\text{year}]$$

$$SAIDI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j t_{sj}}{N_S} = \frac{\sum_{h=(LV,MV,...)} \sum_j \sum_i t_{ji} \cdot n_{jhi}}{N_S} = \frac{t_{s4LV}}{N_S} = \frac{t_{41} \cdot n_{4LV1}}{N_S} = \frac{26 \cdot 100}{310} = 8.39 \; [\text{min/year}]$$

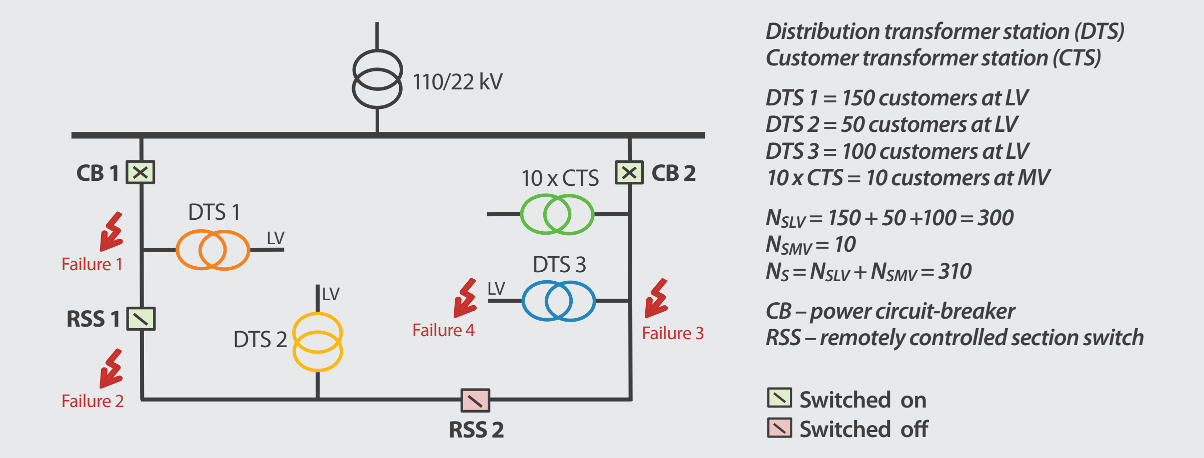
Voltage level indicators

$$SAIFI_{LV} = \frac{\sum_j n_{jLV}}{N_{SLV}} = \frac{n_{4LV}}{N_{SLV}} = \frac{100}{300} = 0.33 \; [1/\text{year}]$$

$$SAIDI_{LV} = \frac{\sum_j t_{sj}}{N_{SLV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jLVi}}{N_{SLV}} = \frac{t_{s4LV}}{N_{SLV}} = \frac{t_{41} \cdot n_{4LV1}}{N_{SLV}} = \frac{26 \cdot 100}{300} = 8.67 \; [\text{min/year}]$$

Alternative with remotely controlled section switch (RSS)

FIGURE 2.28 DISTRIBUTION SYSTEM DIAGRAM (WITH RSS)



Failure 1

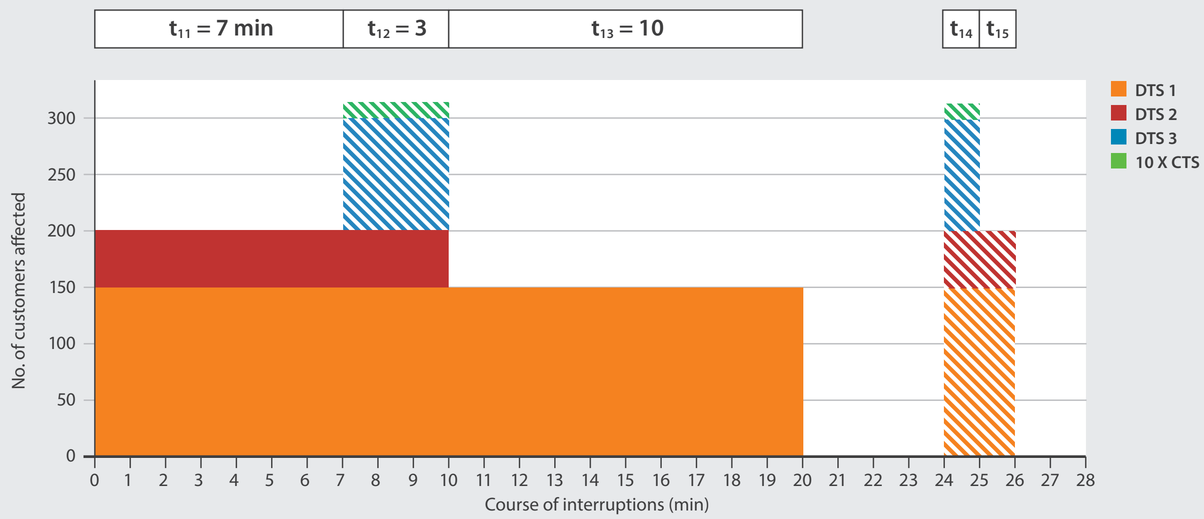
Course of operations in case of failure 1

TABLE 2.21 COURSE OF OPERATIONS IN CASE OF FAILURE 1 (WITH RSS)

Process	Time elapsed from failure (min)
Triggering the CB 1 protection	t = 0
Switching off RSS 1, switching on CB 1, triggering the CB 1 protection – **detecting the location of failure**	t = 4
Switching off CB 2, switching on RSS 2	t = 7
Switching on CB 2 – **partial restoration of supply**	t = 10
Switching on CB 1 – **failure reparation finished**	t = 20
Switching off CB 1, switching off CB 2, switching off RSS 2, switching on RSS 1 – **operations in order to reconfigure the system into the pre-failure state**	t = 24
Switching on CB 2	t = 25
Switching on CB 1	t = 26

Graphic course of interruptions in case of failure 1

FIGURE 2.29 GRAPHIC COURSE OF INTERRUPTIONS IN CASE OF FAILURE 1 (WITH RSS)



Calculation of indicators

System indicators

$$SAIFI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j n_{jh}}{N_S} = \frac{n_{1LV}}{N_S} = \frac{150+50}{310} = 0.65\ [1/\text{year}]$$

$$SAIDI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j t_{sj}}{N_S} = \frac{\sum_{h=(LV,MV,...)} \sum_j \sum_i t_{ji} \cdot n_{jhi}}{N_S} = \frac{t_{s1LV}}{N_S} = \frac{t_{11}.n_{1LV1} + t_{12}.n_{1LV2} + t_{13}.n_{1LV3}}{N_S} =$$

$$= \frac{7 \cdot (150+50) + 3 \cdot (150+50) + 10 \cdot 150}{310} = 11.29\ [\text{min/year}]$$

Voltage level indicators

$$SAIFI_{nn} = \frac{\sum_j n_{jLV}}{N_{SLV}} = \frac{n_{1LV}}{N_{SLV}} = \frac{(150+50)}{300} = 0.67\ [1/\text{year}]$$

$$SAIDI_{nn} = \frac{\sum_j t_{sj}}{N_{SLV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jLVi}}{N_{SLV}} = \frac{t_{s1LV}}{N_{SLV}} = \frac{t_{11}.n_{1LV1} + t_{12}.n_{1LV2} + t_{13}.n_{1LV3}}{N_{SLV}} =$$

$$= \frac{7 \cdot (150+50) + 3 \cdot (150+50) + 10 \cdot 150}{300} = 11.67\ [\text{min/year}]$$

Failure 2

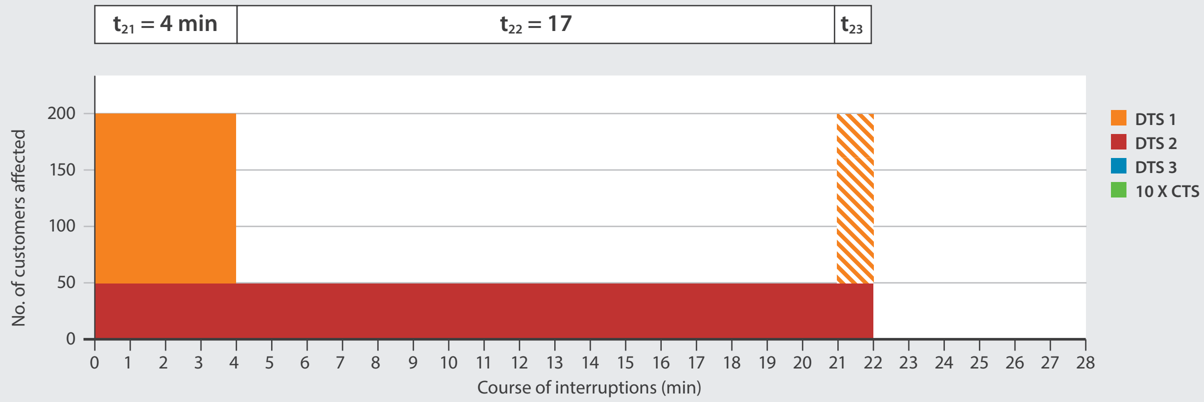
Course of operations in case of failure 2

TABLE 2.22 COURSE OF OPERATIONS IN CASE OF FAILURE 2 (WITH RSS)

Process	Time elapsed from failure (min)
Triggering the CB 1 protection	t = 0
Switching off RSS 1, switching on CB 1 – **detecting the location of failure**	t = 4
Switching off CB 1, switching on RSS 1 – **operations in order to reconfigure the system into the pre-failure state**	t = 21
Switching on CB 1	t = 22

Graphic course of interruptions in case of failure 2

FIGURE 2.30 GRAPHIC COURSE OF INTERRUPTIONS IN CASE OF FAILURE 2 (WITH RSS)



Calculation of indicators

System indicators

$$SAIFI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j n_{jh}}{N_S} = \frac{n_{2LV}}{N_S} = \frac{150+50}{310} = 0.65\ [1/\text{year}]$$

$$SAIDI_S = \frac{\sum_{h=(LV,MV,...)} \sum_j t_{sj}}{N_S} = \frac{\sum_{h=(LV,MV,...)} \sum_j \sum_i t_{ji} \cdot n_{jhi}}{N_S} = \frac{t_{s2LV}}{N_S} = \frac{t_{21}.n_{2LV1} + t_{22}.n_{2LV2} + t_{23}.n_{2LV3}}{N_S} =$$

$$= \frac{4 \cdot (150+50) + 17 \cdot 50 + 1 \cdot 50}{310} = 5.48\ [\text{min/year}]$$

Voltage level indicators

$$SAIFI_{LV} = \frac{\sum_j n_{jLV}}{N_{SLV}} = \frac{n_{2LV}}{N_{SLV}} = \frac{150+50}{300} = 0.67\ [1/\text{year}]$$

$$SAIDI_{LV} = \frac{\sum_j t_{sj}}{N_{SLV}} = \frac{\sum_j \sum_i t_{ji} \cdot n_{jLVi}}{N_{SLV}} = \frac{t_{s2LV}}{N_{SLV}} = \frac{t_{21}.n_{2LV1} + t_{22}.n_{2LV2} + t_{23}.n_{2LV3}}{N_{SLV}} =$$

$$= \frac{4 \cdot (150+50) + 17 \cdot 50 + 1 \cdot 50}{300} = 5.67\ [\text{min/year}]$$

Failure 3 and 4

Switching elements RSS 1 and RSS 2 applied in this alternative do not influence the course of interruptions in case of failures 3 and 4. For this reason the failures 3 and 4 have the same course as in the first alternative with section switches (SS).

2.9.3. Case study: Electricity continuity of supply indicators and monitoring in Algeria

General information

The Law 02-01 on electricity and gas distribution by pipeline, and its implementing provisions mandates the Regulation Commission for Electricity and Gas (CREG) to:

- Propose general and specific standards for the quality of supply and customer service as well as the control measures;
- Approve TSO's development plans and monitor their implementation. In these plans, the TSO is committed to improve the continuity of supply and set targets for the whole period;
- Monitor and evaluate the performance of the obligations of public service: Distribution of electricity is a public service activity which guarantees the supply of electricity, under the best conditions of safety, quality, price and compliance with technical and environmental requirements;
- Provide an opinion on the 5 year engagement of the distributor's performance improving plan, before approval by the Ministry of Energy. These plans cover aspects related to the quality and continuity of energy supply and in relationship with customers; and
- Set up the remuneration of distribution and transmission activities. The determination of remuneration should integrate the incentive mechanism aiming at cost reduction as well as the improvement of the quality of service.

In Algeria, transmission electricity network is operated by a single operator (GRTE) who is in charge of operation, maintenance and development of the network.

The transmission network is composed of an inter-connected network in the north and an insulated network in the south part of the country.

The interconnected electricity network has an aerial predominance (99% of grid length). In 2014, the length of lines which are available in (400 kV, 220 kV and 60 kV) had reached 26,500 km and the number of substations was 390. The installed capacity has exceeded 51,160 MVA. In the same year, the number of industrial clients connected to the transmission grid was 110.

The insulated network included approximately 680 km of lines available in 220 kV and 7 substations EHV/MV. The installed capacity exceeded 500 MVA, for the same year.

The electricity distribution is also a regulated activity, nevertheless it is subjected to concession regime. There are 4 DSOs, each holding a number of concessions. In total, there are 48 electricity concessions.

DSOs are responsible for network management activities (building, operation, maintenance, development) and retail activity (notes, billing, and customer advice and handling complaints).

Distribution network operates at 10,000 V and 30,000 V, known as "MV networks", and at 400 V for 3-phase current and at 230 V for single-phase current, known as "LV network". In 2014, their cumulated length was about 291,000 km. The interface between MV networks and LV network is composed of more than 90,000 substations. The number of LV and MV customers has reached respectively 8,041,635 and 50,590 customers. The electricity consumption has reached 49.2 TWh.

Indicators and data collected for transmission & distribution grid

For transmission grid, 5 indicators are used by CREG for monitoring continuity of supply: number of incidents that occur on the transmission grid resulting in a loss of supply to end consumers, ENS, AIT, SAIDI and SAIFI. These indicators are calculated according to formulas as described in the 4th Benchmarking Report.

For the indicators SAIFI (number/year/customer) and SAIDI (min/year/customer), "customer" refers to industrial customer's substations and transformers HV/MV and EHV/MV (substations interface with distribution grid).

These indicators are collected separately for:
- Interconnected network and insulated network;
- National and regional interconnected network;
- By origin of interruption (distribution, transmission, generation, third party);
- With and without exceptional event;
- Planned and unplanned interruptions; and
- The number of incidents occurred on the transmission system which result in a loss of supply to end consumers is collected by cause (DSO, generation, cable rupture by third party, customer installation, weather conditions, human fault on operation, fault on lines or cables operated by the TSO, fault on TSO's substation).

For distribution grid, 2 main indicators are used by CREG for monitoring continuity of supply: SAIDI and SAIFI as described in the 4th Benchmarking Report, and "customer" refers to MV customer's substation and public distribution substations (MV/LV).

These indicators are collected for each concession, without exceptional event, separately for MV customers and public distribution substation (MV/LV), and determined separately for planned and unplanned interruptions. Only long interruptions (lasting more than 3 min), at MV level, attributable to distribution network are taken into account for indicators determination.

The reports on indicators' achievements are submitted to CREG on a quarterly basis. These reports specify achievements for each indicator according to guidelines document approved by CREG after consultation with the operator.

An annual report is submitted as well, stating the annual achievements of the indicators. This report contains information such as arguments regarding non-achievement of targets and list of all interruptions that occurred on the transmission grid following exceptional events and / or major events (ENS > 50 MWh) giving date, origin and impact (ENS).

On the basis of the received information, CREG performs and submits an annual report to the Minister of Energy. The report gives an overview of the achievement of the indicators in comparison to annual approved targets as well as CREG's opinion on the operator's performance.

CREG has also set up a database on the transmission and distribution grid indicators in order to compare performance at a regional level and provide information that can be used for incentive-based regulation and for investment decisions.

The following table gives an overview of the transmission grid's achievements for the period 2011-2014. These results include all long unplanned interruptions (>3 min), without exceptional events that fall under the responsibility of the TSO.

TABLE 2.23 VALUES OF INDICATORS IN ALGERIA

Indicator (unit)	2011	2012	2013	2014
SAIFI (number/year/customer)	1.82	2.3	1.8	1.4
SAIDI (min/year/customer)	81	77	59	45
AIT (min)	47	77	45	39

Future challenges

CREG expects to implement audit procedures to check data reliability and application of the indicators' determination guidelines.

The continuity data provided by the DSOs has to be improved on a global scale (including all interruptions sources).

2.9.4. Case study: Israel's network

General Overview

Israel's population is about 8 million people, residing on total area of about 21,000 km^2. Israel Electric Corporation is a governmentally owned, vertically integrated monopoly, regulated body, serving about 2.5 million consumers. Until early 2013, 98% of total energy consumed by electricity consumers, used to be manufactured by Israel Electric Corporation. Since early 2013 new large and small Independent Power Producers (IPPs) were introduced to the electricity market, reducing Israel Electric Corporation's market share in the production segment to about 75%. This course is due to continue until IPPs will produce about 40% of the annual national energy level.

IPPs can sell the energy they produce directly to the grid or through bilateral contracts mainly to large private consumers. Electricity and financial transactions are inspected and monitored by the System Operator, which is in charge of the electricity market. Currently the System Operator is a unit within Israel Electric Corporation and not an independent entity as it is the case in countries that underwent comprehensive electricity market reform.

At the end of 2014, Israel Electric Corporation held capacity of 13,617 MW and Independent Power Producers held additional 3,800 MW. Total Installed Capacity in Israel is hence, 17,417 MW. Production by Israel Electric Corporation is 51 TWh and 10 TWh by IPPs. Total energy consumption by Israel Electric Corporation's consumers is 49 TWh and 9 TWh by IPPs' consumers. In the summer of 2015 peak load reached 12,900 MW. Electricity market growing demand is about 2.5% annually. Israeli grid is an "Electricity Island", which means that no back up is available from surrounding countries.

In 2014, AIT in the production sector reached a level of 3 min/year while a 5-year average was 4.1 min/year. Residential Consumption in Israel is about 32% of total consumption. Industrial consumption is about 18% and commercial 32%.

Since the Israeli electricity market is partially competitive, the Public Utility Authority (PUA) defines most of the costs of produced electricity either ex ante or ex post.

The PUA was established by law enacted in 1996 and its 4 main roles are as follows:

1. Setting tariffs for all electricity sectors: production, transmission, distribution and supply (excluding bilateral agreements in the free market between IPPs and private consumers);
2. Setting regulation rules for regulated bodies;
3. Resolving conflicts between consumers/producers and regulated bodies; and
4. Issuing licenses to all players.

Currently, electricity sector reform is debated in Israel and negotiations between the government and the Israel Electric Corporation are still in place.

It should be noted that for historical reasons there are about 220 very small privately owned distribution entities mainly in the kibbutzim communities. Every such community is serving between 100-400 residential consumers and some industrial facilities. The reliability data shown below do not include these distributors. Currently, PUA is taking measures to regulate their activities.

It addition, consumers in East Jerusalem are being served by JDECO, a distribution company serving about 68,000 consumers with total energy consumption of 380 GWh. JDECO's reliability data are not included in this report. Finally, Israel is providing about 6% of its produced energy to the Palestinian Authority and the Gaza strip.

Transmission grid

Transmission grid consists of 3 different voltage levels: 400 kV with 741 km of circuit lines, 161 kV with about 4,594 km of circuit lines, and 115 kV with about 115 km of circuit lines. It should be noted that in the past 2 decades Israel Electric Corporation is slowly replacing the 115 kV grid with a 161 kV grid. The number of substations held by Israel Electric Corporation (public) is 151 units with total capacity of 16,847 MW. Private Substations of private large consumers are 45 with total capacity of 4,500 MW.

Reliability of the transmission grid

The following indicators are usually used in the Israeli system in order to monitor and regulate the transmission grid. These indicators are based on international practices:

AIT = 8,760 * 60 * *ENS / AD*

Where:
AIT Average Interruption Time
ENS Energy Not Supplied
AD Average Demand.

SAIDI – System Average Interruption Duration Index calculated as follows:

$$\bar{U} = \frac{\sum Installed\ Capacity\ Interrupted\ X\ Calculatd\ time\ of\ intrruption}{Total\ Installed\ Capacity\ in\ the\ system}$$

SAIFI – System Average Interruption Frequency Index, calculated as follows:

$$\lambda = \frac{\sum Installed\ Capacity\ Interrupted}{Total\ Installed\ Capacity\ in\ the\ system}$$

CAIDI – Customer Average Interruption Duration Index, calculated as follows:

$$r = \frac{\bar{U}}{\lambda}$$

Table 2.24 below provides data on long interruptions on transmission grid during 2014 as well as data about the number of cases that the grid failed to meet N-1 and N-2 criteria. Table 2.26 provides results of reliability standards such as AIT, frequency of interruptions and unsupplied minutes on the transmission grid. Table 2.25 presents the total system demand, ENS of the system and AIT.

TABLE 2.24 N-1 & N-2 CRITERIA & LONG INTERRUPTIONS ON TRANSMISSION GRID IN 2014

Index	Value	Five-year average	Comments
Number of cases that N-1 Criteria not met	10	7	
Number of cases that N-2 Criteria not met	1	2	
Number of long interruptions in 400 kV lines per 100 km	0	0	No ENS Impact
Number of long interruptions in 161 kV lines per 100 km	1,404	0,536	No ENS Impact
Number of long interruptions in 115 kV lines per 100 km	1,739	1,355	No ENS Impact
Number of long interruptions in 400 kV lines per 100 km	0,809	0,921	ENS Impact
Number of long interruptions in 161 kV lines per 100 km	0,602	1,566	ENS Impact
Number of long interruptions in 115 kV lines per 100 km	0,87	1,014	ENS Impact

TABLE 2.25 AIT, FREQUENCY INDEX (SAIFI) AND UNSUPPLIED MINUTES (SAIDI) IN THE TRANSMISSION GRID

System	115 kV		161 kV		Total	
	2014	5-year average	2014	5-year average	2014	5-year average
AD – average demand (GWh)	147	288	50.624	54.540	50.624	54.807
ENS (MWh)	1	14	68	115	435	598
AIT (min)	3,6	36,8	0,7	1,1	4,5	5,7

TABLE 2.26 RELIABILITY INDICATORS FOR TRANSMISSION GRID

Index	5-year average	Value
AIT for total transmission system	5.69	4.52
AIT for Israel Electric Corporation consumers	0.87	0.00
Frequency of interruptions 161 kV	0.09	0.00
Frequency of interruptions 115 kV	0.07	0.00
Minutes not supplied	0.02	0.00

MV distribution grid

MV distribution grid consists mostly voltage levels of 33 kV, 22 kV, 12 kV. The grid is controlled by Israel Electric Corporation. About 3,000 consumers are connected directly to MV lines. The rest of the consumers are connected via LV lines. Total length of MV lines is approximately 25,000 km. About 40% of them are installed underground. This is a result of a directive set by the Ministry of Energy in 2002 ordering Israel Electric Corporation to install all new distribution lines in urban areas underground. Reliability indices for MV lines are registered and calculated in 2 separate forms. The first form relates to MV lines that are mainly serving MV consumers and the second form relates to MV lines mainly serving LV consumers. The table below provides technical data for 2014 on the MV lines in both forms:

TABLE 2.27 TECHNICAL DATA OF MV LINES IN 2014

MV lines Serving mostly MV consumers	Total	OH	Mixed	UG
Number of Lines	449	45	146	258
Number of transformers	1,285	163	586	536
Installed capacity (MVA)	4,428	481	1,597	2,349
Length (km)	2,182.9	560.5	829.5	792.9
ENS (MWh)	2,850	858	1,513	479
MV lines Serving mostly LV consumers	**Total**	**OH**	**Mixed**	**UG**
Number of Lines	1,804	159	1,046	599
Number of transformers	46,422	5,888	33,220	7,314
Installed capacity (MVA)	28,031	3,010	19,628	5,391
Length (km)	24,226.6	5,251.9	15,934.5	3,040.2
ENS (MWh)	11,669	2,522	8,119	1,028

Reliability indicators for MV lines

Reliability standards such as SAIDI, SAIFI, are measured based on international standards. Tables 2.28 to 2.30 present reliability indices of SAIFI and SAIDI and short interruptions since 2006. It should be noted that short interruptions are defined in Israel as an interruption greater than 20 ms and shorter than 3 minutes.

TABLE 2.28 SAIDI OF MV LINES (MINUTES)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
MV lines serving mainly MV consumers	92,2	68,7	63,1	68,8	73,1	69,9	98,9	224,8	102,1
MV lines serving mainly LV consumers	178,7	133,5	123,6	121,3	144,9	132,2	171,6	234,3	159,4

TABLE 2.29 SAIFI OF MV LINES (NUMBER)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
MV lines serving mainly MV consumers	1,7	1,2	1,2	1,3	1,8	1,7	1,9	2,4	1,8
MV lines serving mainly LV consumers	4,0	2,7	2,6	2,6	3,2	2,7	3,7	4,6	3,1

TABLE 2.30 SHORT INTERRUPTIONS PER 100 KM OF MV LINES

	2006	2007	2008	2009	2010	2011	2012	2013	2014
MV lines serving mainly MV consumers	156,5	162,2	137,1	61,9	96,3	71,5	101,2	65,8	66,0
MV lines serving mainly LV consumers	30,5	35,5	28,9	26,5	30,2	25,7	29,3	35,0	25,2

LV lines (supply)

LV lines consist of a total of 22,000 kilometres of which about 60% of them are installed underground. As mentioned above since 2002 Israel Electric Corporation is not allowed to install overhead lines in urban areas. Table 2.31 presents reliability data for 2011-2014. The average number minutes not supplied per consumer, average interruptions per consumer, average rehabilitation duration and the total consumers affected to the interruptions.

TABLE 2.31 LV GRID RELIABILITY IN 2010-2014

Year	Minutes Not Supplied (SAIDI) (Minutes)	Number of interruptions per consumer (SAIFI)	Average Rehabilitation Duration (CAIDI) (minutes)	Total number of interrupted consumers (for LV only)
2014	11,5	0,072	160	186.765
2013	33,7	0,132	255	336.580
2012	16,7	0,127	132	318.755
2011	11	0,086	129	213.675

Consumer compensation regulation for reliability of supply

In the following cases, a distributer must compensate the consumer with a sum of €0.5/kWh of estimated unsupplied energy due to a long interruption:

1. When an LV consumer experiences an interruption longer than:
   a. 24 hours on single interruption event.
   b. 48 hours of accumulated interruption vents over 1 year.
2. When an MV consumer experiences an interruption longer than:
   a. 20 hours in single event.
   b. 40 hours of accumulated interruption vents over 1 year.

It should be noted that for consumers connected to the transmission grid, the transmission owner must reach an agreement with individual HV consumers regarding acceptable level of interruptions during a year.