SLOVENSKI STANDARD
SIST-TP CLC/TR 50555:2011

01-oktober-2011

Prekinitveni indeksi

Interruption indexes

Ta slovenski standard je istoveten z: CLC/TR 50555:2010

ICS:

27.010	Prenos energije in toplote na splošno	Energy and heat transfer engineering in general
29.240.01	Omrežja za prenos in distribucijo električne energije na splošno	Power transmission and distribution networks in general

SIST-TP CLC/TR 50555:2011 en

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CLC/TR 50555

May 2010

ICS 27.010;29.240.01

English version

Interruption indexes

Indicateurs d'interruption

Unterbrechungsindizes

This Technical Report was approved by CENELEC on 2010-05-07.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. CLC/TR 50555:2010 E

Foreword

This Technical Report was prepared by Task Force 4, (Interruption definitions and continuity indices) of Working Group 1 (Physical characteristics of electrical energy), of Technical Committee CENELEC TC 8X, System aspects of electrical energy supply.

It was circulated for voting in accordance with the Internal Regulations, Part 2, Subclause 11.4.3.3 (simple majority).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

Contents

Figures

Tables

1 Introduction and scope

1.1 Introduction

As a result of the liberalization of electricity markets, System Operators are being increasingly encouraged to report the performance of their electric power systems to other parties, in particular the network users and the national regulation authorities (NRA). While in the past, quality of supply was generally considered as an implicit duty on System Operators, today quality objectives have become more and more definite objectives agreed with the Regulator and/or part of the contracts negotiated with the Network Users. Indeed a number of European Regulators have already defined, or planned to define, quality of supply [1)] objectives (addressing continuity of supply and/or voltage quality) to be met by electric distribution systems. In some countries, quality of supply objectives form part of the incentive-based regulation.

Quality of supply limits can be seen as the outer envelope of performance for each quality of supply parameter. Specific continuity of supply Indices are established by particular Regulators in order to facilitate benchmarking the performance of the System Operators under their jurisdiction. The indices allow System Operators to meet their obligation to routinely report continuity of supply performance. It is important that the objectives are seen not only as achievable but also as being cost effective considering the needs of all the network users.

As customers expect a high continuity of supply for a reasonable price, one of the roles of a System Operator is to optimise the continuity performance of the electric system in a cost effective manner; the role of the Regulator being to ensure that this is carried out in a correct way taking into account the customers' expectations and their willingness to pay. It needs to be recognized that historically the electrical systems in different countries have been designed in different ways based on different technological choices, commercial approaches or climatic conditions.

There is a great variety of reliability indices used within the different European countries. Each country has its own indices, some are system orientated and others are customer oriented. Some countries measure separately the frequency and the duration of interruptions, others combine them into a single value. In addition, not all the countries use the same definitions for interruptions and their classification. For all of these reasons it is currently very difficult to compare the continuity of supply indices between countries.

1) Quality of electricity supply is a collective effect of all aspects of performance in the electricity supply. The quality of the electricity supply includes as a prerequisite reliability of the electric power system, power quality and customer relationships. For the purpose of this Technical Report the term continuity of supply is used for the availability of the electricity.

1.2 Scope

This Technical Report provides guidance on how to calculate continuity of supply indices. These recommended indices are more particularly given for European benchmarking of distribution network performance. For transmission network performance, more representative indices [2] may be used. It presents

– an overview of practices in Europe on long and short interruptions,

– definition of physical interruptions in a harmonized way,

– philosophy and criteria for recommending indices,

– a suggested common approach to continuity indices.

The fact that the networks in different parts of any particular country will be subject to different conditions (e.g. weather and customer density) mean that it is not viable to apply common performance standards to all networks within any one country or any group of countries without making these targets so weak that there is a good prospect of them being achieved in all areas. The present situation where national regulators set performance targets within their own countries is widely regarded as being the most effective mechanism for achieving optimal socio-economic performance. For these reasons this Technical Report does not provide common targets for the number and duration of interruptions that should not be exceeded.

This Technical Report is designed to be a first step towards benchmarking the interruption performance of European countries. Rules on the aggregation of interruptions, in particular short interruptions, have not been considered in this Technical Report, however it is recognised that it might be necessary to describe aggregation rules in a second version of the Technical Report.

1.3 Continuity indices – Needs and applications

Performance indices in general are important tools in decision making for transmission and distribution system asset management. Such indices can be used to translate issues, which might be rather vaguely expressed, into formalized parameters to be used in decision-making. As the reliability of the power system is a key element in power system management, continuity indices are useful to translate objectives such as

- to maximize power system reliability and
- to provide our customers with a supply that has the minimum number of interruptions.

into more formalized objectives and targets aimed to support asset management and stakeholder communication.

In power system asset management, decisions must be taken at different organizational levels within companies. Figure 1 illustrates the main decision levels as well as the most important stakeholders that may influence decisions at different levels.

2) For example, "Average Interruption Time" is commonly used by TSO (AIT = T x ENS / E_T).

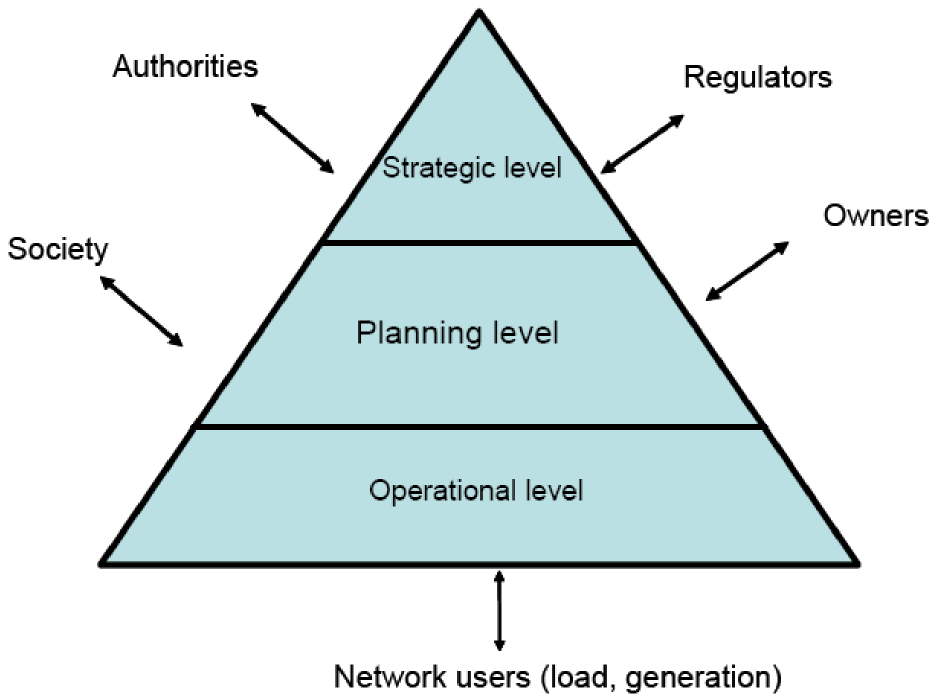

Figure 1 – Network operator organizational levels and stakeholders

The stakeholders set the general requirements, for the business, that are further translated into internal business values and criteria. For example, compliance with the rules and regulations concerning continuity of supply are strategic criteria important for the utilities, authorities and regulators. Obtaining a sufficient profit or return on the assets is an important criterion for company owners while low cost and high reliability of supply are requirements of the customers.

In order to be able to take into consideration all continuity aspects from different stakeholder perspectives, continuity indices are needed.

Continuity indices have several applications:

a) they might be used to measure overall developments and trends;

b) they might be used in benchmarking to identify best practices and learn from others;

c) they might be included in planning objectives and/or planning restrictions;

d) they might be used in contractual arrangements;

e) they might be used by regulatory authorities;

f) they might be used in stakeholder communication.

The list above is rather general and covers company levels, national issues and international issues. As this Technical Report focuses on the international level (European issues), the main applications and criteria for recommending indices are given in Clause 5.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
high voltage (HV)
voltage whose nominal r.m.s. value is 36 kV < $U_n \leq$ 150 kV

[EN 50160:2010]

NOTE Because of existing network structures, in some countries the boundary between MV and HV can be different.

2.2
interruption threshold
voltage magnitude specified for the purpose of detecting the start and the end of a voltage interruption

[EN 61000-4-30]

2.3
low voltage (LV)
voltage whose nominal r.m.s. value is $U_n \leq$ 1 kV

[EN 50160:2010]

2.4
medium voltage (MV)
voltage whose nominal r.m.s. value is 1 kV < $U_n \leq$ 36 kV

NOTE Because of existing network structures, in some countries the boundary between MV and HV can be different.

[EN 50160:2010]

2.5
network operator
party responsible for operating, ensuring the maintenance of, and if necessary developing, the supply network in a given area and responsible for ensuring the long term ability of the network to meet reasonable demands for electricity supply

[EN 50160:2010]

2.6
network user
party being supplied by or supplying to an electricity supply network

NOTE 1 In several countries, the term network user includes network operators connected to a supply network with the same or higher voltage level.

[EN 50160:2010]

NOTE 2 For the purposes of this Technical Report, the terms Network User and Customer are considered to have the same meaning and are therefore interchangeable.

2.7
normal operating condition
operating condition for an electricity network, where load and generation demands are met, system-switching operations are made and faults are cleared by automatic protection systems, and in the absence of exceptional circumstances, i.e.:

- temporary supply arrangement;
- in the case of non-compliance of a network user's installation or equipment with the relevant standards or with the technical requirements for connection;
- exceptional situations such as
  - exceptional weather conditions and other natural disasters,
  - third party interference,
  - acts by public authorities,
  - industrial actions (subject to legal requirements),
  - force majeure,
  - power shortages resulting from external events

[EN 50160:2010]

2.8
planned outage
outage scheduled in advance, for maintenance or other purposes

[IEV 191-24-01]

2.9
reference voltage (for interruptions, voltage dips and voltage swells evaluation)
value specified as the base on which residual voltage, thresholds and other values are expressed in per unit or percentage terms

NOTE For the purpose of this document, the reference voltage is the nominal or declared voltage of the supply system.

[EN 50160:2010]

2.10
residual voltage (U_{res})
minimum value of $U_{rms(1/2)}$ or $U_{rms(1)}$ recorded during a voltage dip or interruption

NOTE 1 The residual voltage is expressed as a value in volts, or as percentage or pu value of U_{din}. $U_{rms(1/2)}$ is used for Class A. Either $U_{rms(1/2)}$ or $U_{rms(1)}$ may be used for Class S. See EN 61000-4-30:2009, 5.4.1.

[EN 61000-4-30]

NOTE 2 The terms U_{din} and referent voltage are considered to have the same meaning.

2.11
r.m.s. value
square root of the mean of the squares of the instantaneous values of a quantity taken over a specified time interval

[EN 61000-4-30]

2.12
SCADA
Supervisory Control and Data Acquisition

2.13
supply interruption
condition in which the voltage at the supply terminals is lower than 5 % of the reference voltage. A supply interruption can be classified as

- **notified**, when network users are informed in advance, or
- **non-notified**, caused by permanent or transient faults, mostly related to external events, equipment failures or interference. An accidental interruption is classified as:
  - a long interruption (longer than 3 min);
  - a short interruption (up to and including 3 min)

NOTE 1 Normally, interruptions are caused by the operation of switches or protective devices.

NOTE 2 The effect of a **notified** interruption can be minimized by network users by taking appropriate measures.

NOTE 3 **Notified** interruptions are typically due to the execution of scheduled works on the electricity network.

NOTE 4 **Non-notified** supply interruptions are unpredictable, largely random events.

NOTE 5 For polyphase systems, an interruption occurs when the voltage falls below 5 % of the reference voltage on all phases (otherwise, it is considered to be a dip).

NOTE 6 In some countries, the term Very Short Interruptions (VSI) or transitory interruptions are used to classify interruptions with duration shorter than 1 s to 5 s. Such interruptions are related to automatic reclosing device operation.

[EN 50160:2010]

2.14
unplanned outage
outage that is not a planned outage

[IEV 191-24-02]

3 Continuity of supply – Interruptions

An interruption occurs when the electricity supply is not available to one or more customers.

An interruption can be the result of system incidents caused by a wide variety of possible events, such as humans, animals, weather, insulator degradation and other natural phenomena or can be caused by the operation of switches to allow the execution of works on the distribution network.

More commonly interruptions are caused by the operation of switches or protection devices (circuit breakers, fuses etc). In the absence of local generation that can provide an alternative supply to a customer's installation, the voltage at the customer's supply terminals will rapidly drop to zero. From a customer perspective, the main indication of a power interruption is that the lights go out and that other electrical equipment stops functioning. From a network operator perspective, an interruption is indicated by alarm signals from control centres (circuit breaker opening, low voltage alarms etc), by the knowledge of planned disconnection operations or by notification from customers that are off supply.

3.1 Background information on interruptions 3)

When considering the continuity of supply of an electric power system, it is very important to consider the difference between "*component outages*" (outages) and "*supply interruptions*" (interruptions). An interruption is a situation when a customer is without electricity. An outage is a situation when a component in the power network (e.g. a cable or a transformer) is disconnected from the rest of the network, either manually or as a result of a protection operation.

Supply interruptions are very often caused by component outages. However not all component outages result in supply interruptions. The start of an interruption is typically due to the start of an outage (a "component failure"). The end of an interruption may be due to a switching operation or due to the end of a component outage (component restoration, repair or replacement).

An outage that results in an interruption for one or more customers can have its origin at various locations in the network. The majority of customers are connected to the low-voltage network, but a substantial part of the interruptions experienced by low-voltage customers is due to outages that occur at higher voltage levels. For most low-voltage and medium-voltage customers, the majority of interruptions are due to outages that occur at the medium-voltage level.

In radial networks (typically at low or medium voltage at remote locations) there is only one supply path to the customers. The outage of a component will immediately result in an interruption and the interruption will only end when the component is restored, or when an alternative supply is provided, e.g. from another part of the network or from generation. In the first case the interruption exactly corresponds to the outage. The duration of the interruption is equal to the restore, repair or replacement time of the outaged component. In the case of an alternative supply, the duration is equal to the time for first notification to the time when the alternative supply was provided. Those low-voltage and medium-voltage networks where redundancy exists are sometimes referred to as "radically operated meshed networks". The start of an interruption corresponds with the start of an outage, but the interruption can be ended (electricity restored) through a switching action ("back feeding"). This is referred to as "redundancy through switching".

In transmission networks and in important medium-voltage networks, the alternative path not only exists but is also used during routine operation, i.e. electricity is supplied via parallel circuits (paths). In the event of an outage one path is disconnected, but there is no interruption because supply is maintained via the remaining healthy path. The customers will not experience any interruption. This is referred to as "redundancy through parallel operation".

3.2 Interruptions as defined by EN 50160

EN 50160 takes into account the characteristics of protection and automatic reclosing systems in use in supply networks.

---

3) Source: 4th CEER Benchmarking Report on Quality of Electricity Supply [7].

On medium voltage overhead networks it is common practice to perform an automatic reclosure after the initial tripping of a line circuit breaker on a fault. The time delay between tripping and reclosing depends on local conditions. The time delay between the circuit breaker tripping and reclosing is often referred to as the “dead-time”, dead-times can vary between a minimum of 0,5 s up to about 180 s.

For lines controlled by circuit breakers set with multiple reclosures, the customers supplied by the line will experience another short interruption followed by restoration of supply or a final tripping of the circuit breaker, depending on whether the fault has cleared spontaneously or persists. Where multiple reclosures are not used the circuit breaker will trip and “lock-out” i.e. not reclose, under these conditions the customers supplied by the line will suffer a long interruption until the fault is cleared and the circuit breaker is reclosed.

In this latter case, the supply will be interrupted until the fault is located and the faulted section of line is isolated for inspection and repair. If an alternative source of supply is provided, this can be brought into service either by manual or automatic switching. For networks with automatic switching, the delay is commonly ranging between 30 s and 3 min.

3.3 Interruption sources

At present in all countries, most electrical power is generated at large power plants and stepped up to high voltage for long distance transmission. At substations, power is stepped down to medium voltage for shorter distance distribution.

For most consumers of electricity, whether industrial, commercial or residential, the power is converted to its final, usable voltage by transformers at or very near to the consumer's location.

Taken together, the entire system of generating plants, transmission and distribution networks can be seen as a “grid” that interconnects the electrical supplies.

As a whole, the “grid” is very reliable and resilient and can continue to operate in the presence of individual component failures, even where these are very large generating plants or substations. However, the networks are still susceptible to events that could lead to interruptions, for example:

- components' failures caused by
  - lightning strikes,
  - animals coming into contact with power lines,
  - wind or ice can force tree limbs onto power lines and occasionally blow down power lines,
  - equipment malfunction,
  - equipment aging degradation,
  - overload
  - bushfires,
  - insulator damage due to acts of vandalism
  - damage to underground power lines by contractors,
  - substation transformer fires or explosions,
  - result of outages on customer owned facilities;
- loss of supply from another network operator;
- operation of switches to allow the execution of works on the distribution network or the result of some request of a third party or a public authority.

In addition to these very common and local causes, there can be other wide area power failures caused by significant disturbances to the Transmission Network where lots of people lose supply for long periods of time. These long interruptions are sometimes referred to as “blackouts”. Although, these events are low probability, they have been experienced in a number of developed countries.

Storms can exaggerate local vulnerabilities by disabling numerous electricity lines at the same time and reduce repair capacity.