# STEERING EFFECT OF DISTRIBUTION REGULATION IN FINLAND

Joel SEPPÄLÄ
Energy Authority - Finland
joel.seppala@energiavirasto.fi

Pertti JÄRVENTAUSTA
Tampere University – Finland
pertti.jarventausta@tuni.fi

## *ABSTRACT*

*Since electricity is becoming more clearly the cornerstone of functioning society, the reliability of electricity distribution is more important than ever. Improved reliability comes with increased costs; evaluation is needed to find balance in reasonable reliability and costs. This study describes the Finnish regulation regime and shows the achieved system-level reliability in the past decades. The system-level reliability shows no significant change after 1990s, though major storms cause fluctuation in the data. Further examination is needed to differentiate environmental factors and the steering effect of regulation from the reliability data.*

## INTRODUCTION

The European Union (EU) has taken a significant role in the electricity market in EU member states by issuing directives ranging from economic processes to the details of the electricity distribution. According to the directive on the electricity market [1], the aim is to build an internal market in electricity so as to achieve a secure and reliable energy market in EU.

In general, the directives steer the national legislation by forming the national regulation regime, which ultimately lead to steering of electricity distribution. The steering effect has been studied for example by Jamasb [2]: "Since the 1990s, regulation has been regarded as playing a key role in the implementation of sector reforms, by improving the efficiency of investments in the networks, enhancing their operation, and facilitating competition in the production and supply of energy over the networks."

The present directive gives the objective of reasonable distribution quality along with the objective of reasonable pricing [1]. Objectives of good distribution quality and reasonable pricing may seem contradictory, since improving service quality in general requires more network investments and maintenance – leading usually to increased costs.

According to Kivikko, overall costs of distribution incurred to society consist of DSOs' costs and distribution interruption costs. The optimal societal cost (c) is achieved, when investment costs of distribution reliability (b) equals the interruption costs (a). The principle is shown in fig 1. [3]

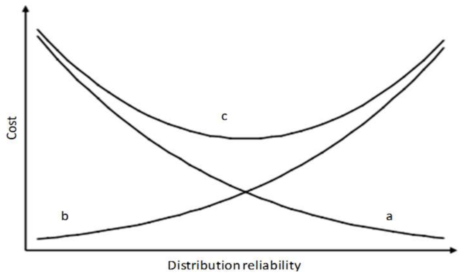


Fig 1. Distribution reliability and cost functions in principle. Adapted from [3].

As seen in fig. 1, exceeding the requested level of distribution reliability leads to increased costs to the society. As the distribution reliability may be presumed to be a function of investments in network, the function of interruption costs is more complex, depending on user type, time of day/year and the length of interruption [4].

When minimizing overall societal costs of distribution, the central point is to determine the optimal level of distribution reliability [2]. This evaluation duty is given to the independent national regulator authorities (NRAs) [1].

### Scope of study and definitions

The scope of this study is to describe the Finnish electricity distribution regulation regime in the context of EU-directives and to show the progress of distribution reliability according to interruption statistics collected in Finland.

This study fits together system-level interruption time series from different sources to describe and find evidence on distribution reliability progress in longer perspective. The main research question is to examine through research on regulation data, how the regulation has affected into distribution reliability.

Since the legitimacy on regulation comes from the present directive, definitions in this study are accordance to the directive. While *supply* means the sale of electricity, *distribution* means the transport of electricity on distribution systems, but does not include supply. According to the directive, *security* means both security of supply and provision of electricity, and technical safety. [1]

Since the scope of this study is in the technical reliability of the distribution network, the term *distribution reliability* is used in this study. The *distribution quality* is mentioned, when referring into technical quality, including reliability and other physical characteristics of voltage, and the *distribution service quality* refers to the overall distribution service, including metering, billing and customer service.

## REGULATION REGIME IN FINLAND

The reference to the distribution reliability in the first electricity market directive was superficial: "The distribution system operator shall maintain a secure, reliable and efficient electricity distribution system in its area, with due regard for the environment." [5] Second directive on electricity market concentrated in market development, though it gave a possibility to impose public service obligations including also the security of supply. The third electricity market directive issued more precise obligation, "The distribution system operator shall be responsible for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity, for operating, maintaining and developing under economic conditions a secure, reliable and efficient electricity distribution system in its area with due regard for the environment and energy efficiency" [1]

The Finnish regulation regime is based in legislation, following from the present EU directives. In addition to the general obligations of good quality, the first concrete regulation *mechanism* on distribution reliability was the standard compensations implemented in the revised energy market act in 2003 [6]. The first *economic regulation model* was introduced in 2005 and was based in combination of Rate-of-Return type regulation including elements on efficiency [7]. A distribution quality incentive was adopted into the economic regulation model in 2008 [7], and *distribution reliability standards* were introduced in 2013 [8]. The progress is visualized in fig 2.

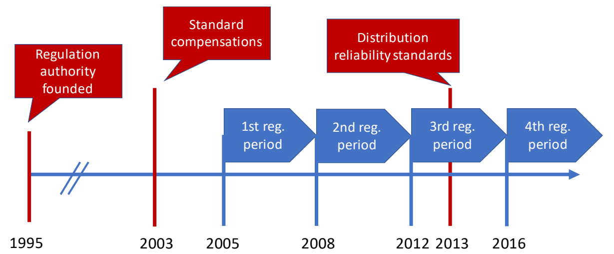


Fig 2. Distribution regulation milestones.

### Regulation Methods

Electricity distribution regulation can be divided into direct and indirect regulation, according to the scope of evaluation and timeline of actions. Direct regulation is an explicit regulation method to ensure that DSOs perform at least according to the norms and standards in legislation. Direct regulation applies for example to voltage levels and exceptional number of interruptions.

Indirect regulation refers to implicit steering effects on distribution system operators' (DSOs') economic environment. Indirect regulation steers companies to provide good quality while being economically efficient. The scope of indirect regulation is system-level performance, though DSOs are treated individually. The timeline of indirect actions is from years to decades.

### Direct Regulation

Direct regulation ensures that the DSOs comply with legislation and/or technical standards. By having a network operator license approved by the national regulation authority, the DSO is presumed to meet with the obligations. If a customer suspects a violation of obligations, the customer is eligible to call for investigation. The regulator must give a decision on the suspected violation. In case of a violation, the decision requires the DSO to take corrective actions. [9]

Since calls for investigation typically consider one customer, possible corrective actions made by the DSO have little influence on system-level reliability indexes. However, setting obligations for quality and reliability steers the DSO to perform at least to the required level.

### Indirect Regulation: regulation model

The cornerstone of indirect regulation is the model of economic regulation. The current regulation model in Finland evaluates DSOs' economic assets and performance in electricity distribution quality. In short, DSOs are eligible to collect a reasonable compensation for their assets put into the network. The compensation is increased or decreased according to the DSO's performance in the distribution process. These incentives have been adapted to the regulation model in phases. Currently the model includes elements e.g. on economic efficiency and distribution quality; therefore, DSOs are expected to improve efficiency and quality. [10]

### Indirect Regulation: standard compensations

Another regulation method is standard compensation for long interruptions, implemented in legislation in 2002 and revised in 2013. DSOs must provide customers compensation for annual service fees for every interruption longer than 12 hours. Customers do not have to apply for these compensations, DSOs must give compensation automatically. Compensations lower the economic turnover and therefore operational profit in economic regulation [8].

Usually compensations are launched only for major weather incidents. In 2011, which included winter storm Tapani, compensations of 46 M€ were granted to customers, which was 3.1% from overall turnover of DSOs that year [11]. Since the storm concerned only some of the

DSOs, the proportion compensations of annual turnover in concerned DSOs was even greater. Therefore, it is presumable that the essential steering effect is to avoid launching compensations.

### Indirect regulation: instructional method

The third indirect regulation method results from direct obligation in legislation. A direct distribution quality requirement was set in the electricity market legislation in 2013: after a transition period, a disturbance no longer than 6 hours in urban areas, or 36 hours in rural areas is allowed due to storm or snow load. [8]

The explicit quality requirement is here classified as an indirect regulation method because of another requirement: development plans from every DSO. Every DSO's development plan must represent actions for maintaining and increasing distribution reliability so that the distribution reliability requirements will be met after the transformational period. The plans are updated every second year; the regulator follows how the plans are fulfilled and may require plan adjustments. The plans are expected to increase network resilience in poor weather conditions, though the timeline of plans is long, from 15 to 23 years. [8]

## DESCRIBING DISTRIBUTION RELIABILITY

Distribution reliability is often described with indexes on interruption duration and number of distribution interruptions. Depending on the purpose, the indexes may be calculated to describe for example the average number of interruptions for all customers (SAIFI), or for those customers, who suffered from interruptions (CAIFI). The interruption data may also be weighted by distributed energy (SAIFI-e), or it may include only the momentary interruptions (MAIFI). Also, other indexes may be used for describing distribution reliability.

Presently, "Energy Authority", the Finnish national regulation authority (NRA), collects energy weighted indexes on number of interruptions (SAIFI-E) and interruption duration (SAIDI-E), to describe the distribution reliability. Indexes are differentiated to short (< 2 min) and long (> 2 min) interruptions according to standard on interruptions. Furthermore, absolute number of disturbances are collected.

Though Energy Authority was founded first in 1995, there is a long history in Finland of collecting distribution reliability data from distribution networks. The distribution reliability data has been voluntary collected by a branch organization "Finnish Energy" and its predecessors for decades. This enables a relatively long data set for analyzing distribution reliability progress. However, conclusions should be made carefully, since practices and definitions in data collection have changed. For example, distribution automation has improved interruption logging since the late 1970s, but the lack of a comprehensive network information system might have led to inaccurate distribution reliability data. Practices in calculating indexes and interpreting interruption series may have varied also. Comprehensive documentation on data collection methods before the 1990s was not found for this study.

Despite possible inaccuracies in data, for gathering an understanding of distribution reliability progress, average interruption duration caused by network disturbances in Finland from 1968–2005 is shown in fig 3. [12], [13]

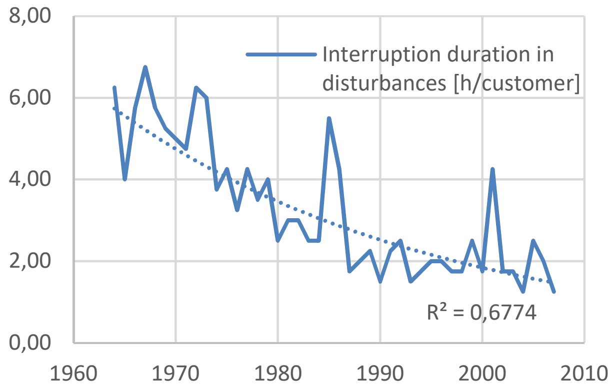


Fig 3. Average interruption duration in disturbances in Finland, [h/customer, year] and exponential regression fit with correlation of 0,677.

Interruption data in fig 1 shows that distribution reliability has improved considerably since the 1960s. Despite improvement in distribution reliability in the past, however, the annual interruption duration level of 1.5-2 hours has not decreased since the 1990s. The time series in fig. 1 is later referred as the "historical data"

Distribution reliability data is declared public by a decree given by the NRA and therefore it is available for this study. Since every DSO have been obligated to provide precisely described information, this information is a solid fundament for further examination. Later in this study, the data collected by the decree is referred as the "regulator data". [14]

The corresponding time series on average interruption duration in regulator data was compared to the historical data for the overlapping years from 1996–2004 and found coherent. Though correlation for the overlapping time series is 0.88, the level of interruption duration is on average 26% higher in regulation data than in the historical time series.

Since the interruption duration is on the same *level* and variation is coherent, the time series may be presumed to describe approximately the same phenomenon though it cannot be connected into one continuous series.

## Distribution reliability since regulation

Time series concerning *average interruption duration* (SAIDI) was discontinued in 2014, but the *energy-weighted average interruption duration* (SAIDI-E) is available from 2005 on. For further analysis, these time series were compared for overlapping time (2005–2014). Correlation is strong, 0.996. Since the time series are congruent, an approximation was built to gather a longer time series. The approximation was constructed by extrapolating SAIDI-E data with the SAIDI data and vice versa. Resulting time series are presented in fig 2. [11]

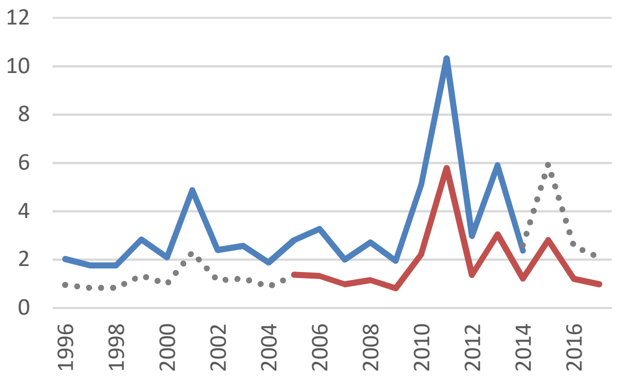


Fig 4. Average interruption duration (blue) and energy-weighted interruption duration (red) [h/customer, year]. Interpolated data marked dot line.

The data show that the level of energy-weighted interruption duration is 1–1.5 hours, though fluctuation is significant. Relevant regression function is not available due to fluctuation in later years.

## Analyzing distribution reliability progress

The historical data on interruption duration show significant improvement in distribution reliability until the 1990s but no further improvement thereafter. This is contradictory to the general aims of increasing distribution reliability in the Electricity Market Act and European Directives, but on the other hand, the concrete elements of distribution quality regulation were first time implemented in the Finnish regulatory regime in 2003.

As the only significant changes in system level reliability data are the increased peaks in interruption duration, other methods are needed to analyze the reliability progress.

## Hypothesis on reliability progress

Despite significant fluctuation in interruption duration in the 2010s, the general hypothesis is that distribution reliability will improve. The hypothesis is based on legislation which encourages/requires DSOs to avoid long interruptions and on regulation methods that reward companies that improve distribution quality.

In legislation, maximum interruption duration of 6 hours in cities and 36 hours in rural areas are considered acceptable due to storm or snow load after transition period of 15-23 years. It is to be expected that though interruptions will still occur, but the duration of single interruptions will be limited to 6/36 hours.

An important method for improving distribution quality is to renew the network with resilient structures. Though the fault probability depends also e.g. on environmental factors, a demonstration is made to show the slowness of changes in system level interruption duration. Assuming the life cycle of every component to be 40 years and the age of the network linearly distributed, annually the oldest 1/40 of the network must be renewed to maintain its current age. If every renewed component is assumed to be fault-free, the interruption duration would be close to zero in 40 years.

To conclude the hypothesis, 1) Single interruptions due to storm or snow loads are expected to be limited to 6/36 hours in year 2028-2036 and 2) Improving network resiliency may decrease continuously the number of overall interruptions - and therefore interruption duration - but the volume of effect remains unknown.

## Identifying changes in reliability according to hypothesis

The time series on distribution reliability are only half the life cycle of an average network component. The base level, excluding years of extreme weather conditions, remains in level of 1-1.5 hours. In system level, the change in the base level of reliability is not shown.

The interruption durations for the years 2001, 2010, 2011, 2013, and 2015 differ significantly from the base level. In historical time series presented in fig 1, the year 1985 also differs considerably from average. In those years, intense storms covering wide areas of Finland caused long interruptions. Though the peaks in interruption duration show a decreasing trend in the 2010s, conclusions should be drawn carefully, since time series concern the whole of Finland, but area and intensity of storms have not been analyzed here. Despite that, it can be concluded that at least wide and intense storms may be identified in system-level interruption duration data.

Looking more closely at winter storms, Janika in 2001 caused interruptions in electricity distribution for over 400,000 customers [15], storm Tapani (2011) for 300,000 customers [16] and the latest winter storm Aapeli in 2019 for 120,000 customers [17]. Despite the lowest number of customers suffered from interruptions in storm Aapeli, the wind speeds reached greatest ever recorded in Finland of 32.5 m/s [17]. This shows that the effect of storms on electricity distribution varies and should be studied and described more closely from the local level data.

According to Finnish Energy, 21% of all interruptions follow from damaged components or operational failures and the majority of interruptions follow from external causes, e.g., weather conditions or construction [13]. Latter leads to a general observation on interruption duration figures: since an interruption may be considered as an error in distribution process, the interruption duration figures show merely *unreliability* – cases where the network has failed to resist the external conditions. Furthermore, resulting reliability is a combination of component properties and external conditions; an overhead line and an underground cable may succeed similarly on a usual calm sunny summer day, but probability for a disturbance in icy rain is generally greater for the overhead line. Therefore, the reliability should be concerned as a probable ability to resist external conditions.

For further examination, three considerations are proposed to identify changes in reliability: 1) defining a general electricity distribution process and including environmental changes in the process, to simulate changes in distribution reliability, 2) analyzing fault statistics in major disturbances, since the resilience of the distribution network is actualized in poor weather conditions and 3) analyzing fault statistics especially on single companies level.

## CONCLUSION

Since the electricity distribution regulation is a complex set of methods and there are multiple contradictory targets for regulation, evaluating outcomes is a complicated, though important, task. This study has described distribution reliability progress on system level based on the latest available regulation data. The base level of interruption duration in 1996-2017 is 1-1.5 hours and shows no significant change, but fluctuation causes uncertainty in the reliability trend. Based on legislation and regulation targets, the hypothesis on future progress is that the number and duration of long interruptions will decrease.

Since the interruption indexes are strongly affected from external conditions, such as storms, identifying changes in distribution reliability need also analyze on environmental factors. Further analysis is needed to analyze the connection between regulation and distribution reliability.

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