Electrical Power and Energy Systems 97 (2018) 120–126

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Assessing the contribution of automation to the electric distribution network reliability

Carlos Girón[a], Fco Javier Rodríguez[a,*], Laura Giménez de Urtasum[b], Samuel Borroy[b]

[a] Department of Electronics, University of Alcalá, Campus Universitario, Escuela Politécnica Superior, Alcalá de Henares, Spain
[b] CIRCE Foundation, Zaragoza, Spain

ARTICLE INFO

Keywords:
Distribution power network reliability
Communications latency
ASIDI
SAIDI
TIEPI
KPIs

ABSTRACT

Electrical distribution systems have changed significantly in the last years. Todays it is necessary to optimize the quality and quantity of power delivered to customers and to respond to current energy demand. In this sense, electric utilities are involved in network automation processes, supported in information and communication technologies, to improve network efficiency, reliability, security and quality of service. This paper aims to quantify the improvements achieved in the reliability indices with the automation of secondary substation (SS). As this automation process lies in the use of non-ideal communication channels, their latency and availability are considered. In order to complete the analysis from an experimental evaluation, this methodology has been applied to a real distribution network, included in the framework of several research projects developed in EU (European Union). Since the value of this reliability index has a remarkable influence on the revenues of the distribution system operator companies, these results provide a useful incoming for the strategic development of the distribution networks.

1. Introduction

Distribution System Operators (DSOs) should adapt their network operations and business to newly developed technologies and solutions for medium and low voltage grids [1]. Demand management and the increase of the use of distributed generators have emerged as some of the main concerns during the last years in electric power distribution [2]. To address these recent concerns, DSOs have equipped their networks with information and communication technologies in order to improve network efficiency, reliability, security and quality of service [3]. It is important to remark that system reliability is not the same as power quality [4]. Reliability is associated with sustained and momentary supply interruptions, whereas power quality involves faster electrical disturbances such as voltage fluctuations, abnormal waveforms and harmonic distortions.

The automation of secondary substation (SS) is required to facilitate network integration and control of distributed generation, local storage and manageable loads, to ensure and even improve power quality. The rapid restoration of the power supply after outage situations is a key factor in the reliability of the network. Therefore, network automation should allow developing a self-healing system able to restore service as quickly and efficiently as possible [5].

A considerable interest in reducing economic losses suffered by power system customers due to reliability events has been identified recently by the electric sector stakeholders. This situation, together with the changing regulation of the power industry, has motivated the definition of reliability based rates or penalties to power distribution companies. According to current regulatory models around the world, such as the Spanish or the Finnish, the investment in the improvement of system reliability is motivated because reliability has a direct effect on the revenues of the DSOs. Specifically, an increase up to 2% of the yearly remuneration without incentives may be given to a DSO due to reliability improvement [6]. In this sense, network automation involving remote-controlled disconnectors and fault passage indicators (FPI) belong to the basic structures in distribution technology, and these devices play an important role in the improvement of reliability [7,8].

Therefore, DSOs have mainly two options to enhance reliability: the first is the installation of an undefined number of these network automation devices and thereafter to check the change in reliability. The second choice is to calculate reliability through the simulation of the effects of this network automation equipment over the modelled DSO network and, consequently, install the appropriate devices in the network. Obviously, the first option may lead to uneconomical results; whereas the second one provides the possibility to assess whether the economical effort necessary to install the network automatic devices is profitable before the real equipment installation is carried out.

* Corresponding author.
E-mail addresses: carlos.giron@depeca.uah.es (C. Girón), franciscoj.rodriguez@uah.es (F.J. Rodríguez), lauragdu@fcirce.es (L. Giménez de Urtasum), sborroy@fcirce.es (S. Borroy).

http://dx.doi.org/10.1016/j.ijepes.2017.10.027
Received 22 November 2016; Received in revised form 16 October 2017; Accepted 22 October 2017

On the other hand, communication networks provide necessary infrastructure allowing a DSO to manage these devices from a central location. The communication comprises several important aspects: the communication channels used to transfer information as well as the way to carry it out; the services provided by each resource; and the information technologies [9,10].

In the smart grid environment, heterogeneous communication technologies and architectures are involved. Communication networks should meet specific requirements, i.e., reliability, latency, bandwidth and security, for automation purposes. The election of the communication channels has been dealt with in several previous works. Examples of the use of wireless networks could be found in [11]. The use of Ethernet networks has been presented in various works as [12].

So, the development of smart grids in the distribution domain can be achieved by investing in information and communication technologies (ICT). However, although these technologies already exist, implementing them in the extensive distribution network would be prohibitively expensive. Therefore, the focus must get fed back to determine the optimal level of technology deployment that would achieve these objectives at minimum cost. This is easy to understand thinking about the dimensions of the electric current distribution system for a medium country: about some million kilometers and a huge number of customers. If this one-way system, whose basic function is to provide energy through these lines to customers, adds the bidirectional option generation or storage dispersed case of electric vehicles, then it becomes a more complex and exciting challenge to find balance versus technology investment [13,14].

Under this framework, this paper presents novel methodology developed to calculate one of the most commonly used reliability index in the electric field, which is the Average System Interruption Duration Index (ASIDI), including in the model worst case latency and availability of communication channels. In the literature, few studies focused on the role of automation and communication infrastructures in the probabilistic power system reliability assessment [15].

The paper is structured as follows: after this introduction, the most common power system reliability indices are discussed in Section 2. Section 3 presents the variability of the reliability indices measured in real networks in several countries depending on the year. Section 4 presents channel communications modelling. The methodology of the ASIDI calculation is detailed in Section 5. Section 6 includes the results obtained by applying the developed methodology to a real distribution network and Section 7 collects the conclusions.

2. Reliability indices: Definition

Continuity of energy supply is determined by the average number and duration of outages suffered by a user for a period of one year in a given area.

These two parameters are defined as:

a) The outage time equal to the time elapsed between the beginning and the end of the power cut, measured in hours. Total interruption time is the sum of all downtime during a specified period.
b) The number of interruptions. The total number of interruptions is the sum of all interruptions therein during a specified period.

Interruptions can be unexpected or planned; the latter allows the execution of scheduled maintenance work on the network, in which case consumers should be informed in advance by the distribution company, with prior authorisation of the competent authority.

Depending on the region or the country where the power system reliability is studied, a wide range of indices are available to be used. The following reliability indices have been identified as the most common and comprehensive performance metrics from Europe and the U.S. state rules, [16]:

- System average interruption frequency index (SAIFI): Gives the average number of sustained interruptions per customer per year.
- Momentary average interruption frequency index (MAIFI): Like SAIFI, but related to momentary interruptions.
- System average interruption duration index (SAIDI): Provides the average duration of interruptions per customer per year.
- Average system interruption duration index (ASIDI): This indicator measures the average duration of supply interruptions per served energy per year.

As it can be deduced, there are remarkable differences between these indices. SAIDI is representative of the average interruption time, but it is neither weighed according to the consumption nor the installed power. On the other hand, ASIDI includes the influence of the consumption of the interrupted customer. In addition, in some countries, the installed capacity of the SS is used to weigh the ASIDI instead of the served energy, resulting in the TIEPI (Equivalent Interruption Time Related to the Installed Capacity) reliability index.

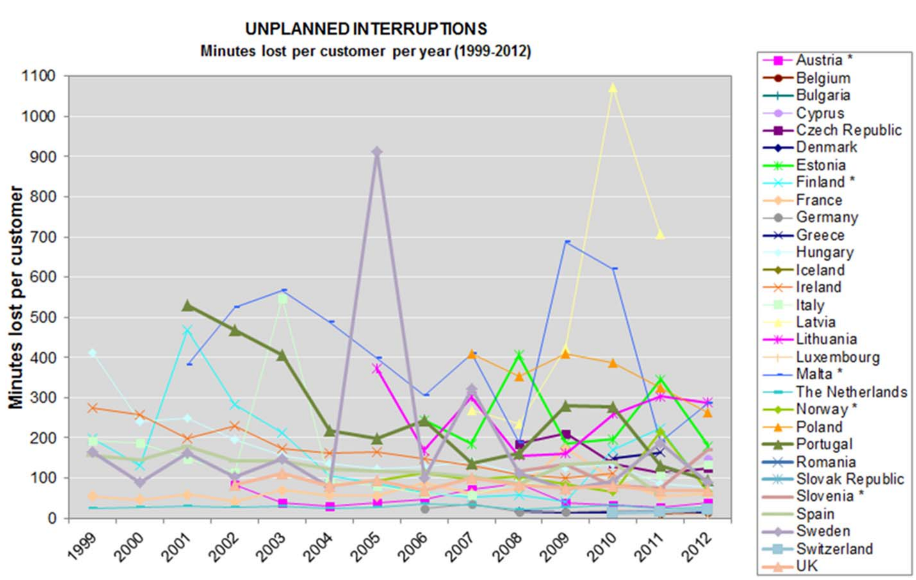

Fig. 1. SAIDI and ASIDI values in Europe, from 1999 to 2012.