Electrical Power and Energy Systems 37 (2012) 110–116

Contents lists available at SciVerse ScienceDirect

Electrical Power and Energy Systems

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

Investigating the use of probability distribution functions in reliability-worth analysis of electric power systems

O. Dzobo *, C.T. Gaunt, R. Herman

Department of Electrical Engineering, University of Cape Town, Rondebosch 7701, South Africa

ARTICLE INFO

Article history:
Received 6 September 2011
Received in revised form 16 December 2011
Accepted 18 December 2011
Available online 9 January 2012

Keywords:
Business customers
Customer interruption costs
Probability distribution function
Reliability-worth

ABSTRACT

The use of probability distribution functions to describe reliability-worth input parameters is fairly new compared to using average values. Reliability-worth indices of power systems are frequently calculated as average values and convey little information about risk. In this paper beta probability distribution function was used to model time-dependent customer interruption costs as an input parameter to reliability-worth analyses of power systems. Time-sequential Monte-Carlo simulation technique that can handle time dependence of the input parameters was employed in the analysis. The results revealed that more information can be derived from the reliability-worth indices when probability distributions are used to describe the reliability-worth input and output parameters.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Power systems comprising generation, transmission and distribution, are subjected to many adverse events such as accidents, random component failures and weather conditions resulting in power interruptions. These kinds of events are beyond the control of a utility, but they can be taken into account when deciding the level of supply reliability at which the system should operate. In order to relate investment costs to the level of supply reliability, it is necessary to quantify reliability in monetary terms. In reliability cost and worth analyses of power systems, the reliability-worth experienced by customers is compared with the cost incurred by the grid owner [1]. Customer interruption cost (CIC) is used as a substitute in the assessment of reliability-worth in electric power systems [2]. Numerous studies have been conducted to provide estimates of CICs and a wide range of methodologies has evolved. However, the use of different probability distribution functions (PDFs) to model CIC for planning and operating reliability-worth studies is uncommon.

Reliability-worth indices are determined for a given system or component and it is the interpretation of these indices that sheds light on how reliable the system is. Most reliability cost and worth analyses in previous research use average values for the input parameters and present the reliability-worth outputs as estimates of the mean values. Using average values for the input and output parameters ignore the shape of the parameter PDF. Several indices have been proposed for reliability-worth studies (e.g. expected CIC (ECOST), interrupted energy assessment rate (IEAR) and cost of unserved energy (CUE)). The selection and definition of these indices are very much dependent on the methodologies used and the purpose of the study. To estimate consequences for the customers, the reliability-worth index ECOST is computed and presented in this paper. The work presented in this paper was carried out on a power distribution network.

Several techniques have been developed for use in evaluation of reliability-worth indices of a given power system. The techniques can however be grouped as either deterministic or probabilistic. Deterministic (also termed analytical) techniques have been used for many years in reliability-worth analyses of radial distribution systems to calculate the average load point reliability-worth indices [3]. The average load point reliability-worth indices are estimated using a mathematical model that uses average input parameter values (e.g. repair time, switching time, CIC values, etc.). They are limited for the work proposed in this paper because it is almost impossible to apply these techniques when non-constant parameter inputs are considered.

Probabilistic techniques have advantage over deterministic techniques in that they are able to account for the stochastic behaviour of power networks [4,5]. The main probabilistic techniques are simulations, the most important being Monte-Carlo simulations (MCSs). The time sequential MCS plays an important role in the work presented here because it takes into account the stochastic nature of power systems in a chronological order. This approach allows for the inclusion of the time dimension in the reliability-worth analysis [6]. The inputs of a reliability analysis, such as component failure rates, restoration times and CIC values, are treated as random rather than average values and are allowed to

* Corresponding author. Tel.: +27 71 397 4505.
E-mail address: odzobo@yahoo.com (O. Dzobo).

0142-0615/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2011.12.013

take on values according to chosen PDF [7,8]. The performance of time sequential MCS is independent of the size of the network being analysed.

For the purpose of this research, all cost are given in South African Rand (R). 1€ (Euro) is equivalent to R10 approximately.

2. Measuring CICs

Several studies have been conducted to provide estimates of CICs. There is however, no universal agreement on the appropriateness of methodologies applicable to particular situations nor on the interpretation of the results obtained, but some appear to be more acceptable and useful to the industry than others.

CICs are challenging to estimate since they are functions of many different factors [9]. The customer survey approach [10], in which customers are specifically interviewed, is regarded by many researchers as the most practical and reliable process to obtain these costs. The strength of the method is that customers are in the best position to know their own costs [11–13]. This is also supported by the results from both analytical and blackout case studies, which show that for interruption cost assessment to be realistic, the cost information should be customer specific [11]. However, the main drawback with survey methods is that the results are quite sensitive to the survey design and implementation [1,10].

The impact of a power interruption is defined by the interrupted activities due to the interruption [14]. Customers use electricity in different ways that characterises their sectors. Therefore, CICs are assessed by surveys for different customer sectors, usually according to a particular standardized industrial classification (SIC) [15–17]. For example, customers can be divided into: residential, industrial, governmental and public, agricultural, and commercial customers. To be able to quantify how disrupted activities affect the interruption cost, customer valuations of these effects are also needed. In customer surveys, these valuations are often included and made on an inconvenience scale [14,18].

With a customer survey, only the direct rather than indirect costs are collected. In direct costing methods, customers are asked to identify the impact of a particular hypothetical outage scenario and the associated costs [10,15]. Depending on whether social or economic costs are collected, different survey methods are used. For all customer sectors, less so for the residential sector, the direct costs mostly have an economic impact. Therefore, a direct costing method is recommended for these customer sectors [19]. Residential surveys use contingent valuation methods that are designed to capture more intangible costs such as inconveniences. In the contingent valuation methods, customers are asked to state how much they are 'willing to pay' (WTP) to avoid an outage or how much they are 'willing to accept' (WTA) in compensation for an outage. A direct costing method can also be applied to the residential sector. It is recommended that several different methods be used for the residential sector [19].

Performing a customer survey is a time-consuming and expensive task that requires a large effort to collect a sufficient data sample [10]. Interruption cost data derived from surveys therefore includes a small sample of the possible outage events. Commonly, only the interruption costs for a worst case scenario is surveyed for a few outage durations [20]. Customer surveys will always generate some "bad" data, such as unrealistically high cost estimates. Therefore statistical analyses of the raw data should be conducted before the data are used [10]. There are procedures for identifying outliers [21].

The costs incurred due to power supply interruptions can be presented as a function of outage duration, and when expressed in this form it is known as a customer damage function (CDF) [22]. The CDF can be determined for a group of customers belonging to particular sector. In these cases, the interruption cost versus duration plots are referred to as individual customer damage function (ICDF). ICDF are usually based on CIC data for the worst case scenario as shown in Fig. 1 [18].

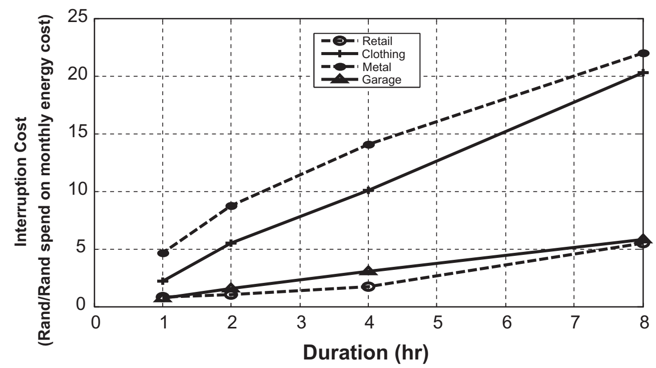

Fig. 1. Individual customer damage function models for different customer sectors [14].

Two different procedures for calculating the CDFs are: the average process and the aggregating process [23]. In the average process, the CIC data from the survey is first normalized. After normalization, an average value of the normalized cost for each customer sector and surveyed duration is calculated. The second procedure, the aggregating process, first summarizes the CIC data for each customer sector and duration. The result is then normalized by division of the summation of normalizing factors of each sector [10,20]. Common normalization factors are total annual electricity consumption, peak load or energy not supplied.

In Fig. 1, the normalization factor is average monthly energy cost and the unit of the ICDFs is therefore 'Rand' per 'Rand spent on monthly energy cost' [18,24,25]. The normalization process will give the values of the CDF marked with different symbols in Fig. 1. To estimate the CIC for any duration, linear interpolation is used between these values. Since the CIC data is only obtained for a worst case scenario, the CDF shows how the worst case cost varies with interruption duration.

The linearization of the costs with the duration of the interruption does not describe the dispersed nature of CIC that occurs for individual consumers as well as for the different durations [26,27]. It is therefore unrealistic to use average CIC values for the different durations considered and to assume the CIC value to have the same value 100% of the time. For realistic analyses, variability in CIC cannot be ignored and should be included in the model being used to represent it. Since PDFs allow for variation about the mean, they are a good tool for describing statistical variation (uncertainty) in the CIC modeling, from which the significance of including statistical variation in CIC modeling becomes clear.

Several PDFs have been identified for use in CIC analyses. Some include the Normal, Poisson, Weibull and Beta distributions [14,24,28]. However, relatively little work has been published on estimating reliability-worth indices associated with CIC derived from PDF. A number of multiplicative models have been applied to capture the time dependence of CIC. Studies show that the time dependencies in inputs are important when estimating the annual CIC, and ignoring them may lead to different planning and operational decisions [29].

2.1. Application of PDFs to reliability-worth outputs

The reliability-worth indices of a power system are stochastic values dependent on a network's topology and operating philosophy and conditions. The average values show how reliable the system is on average, but it is interesting to investigate the risk of extreme

Download English Version:

https://daneshyari.com/en/article/399953

Download Persian Version:

https://daneshyari.com/article/399953

Daneshyari.com