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Modeling and simulation of long term stochastic assessment in industrial microgrids proficiency considering renewable resources and load growth

Seyyed Mostafa Nosratabadi, Rahmat-Allah Hooshmand*, Eskandar Gholipour, Sadegh Rahimi

Department of Electrical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran

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ABSTRACT

Distributed Generation (DG) resources in industrial microgrids affect the reliability parameters in the networks. Therefore, the aim of the paper is to assess the reliability of industrial microgrids using a proposed composite index in the presence of DG and Demand Response (DR) resources. The reliability evaluation is performed on the basis of sequential Monte-Carlo method with regard to the available time load. Here, the widely used renewable generations such as wind and photovoltaic ones are used. Since the output of this type of DGs depends on random variables such as wind speed and solar radiation, a number of scenarios have been considered to determine the output amount per hour. The newly presented composite index shows the changes of conventional reliability indices (SAIFI, SAIDI, and EENS) per kW of DG installed. Due to the increase of industrial loads, a 10-year study is scheduled for both islanding and grid-connected performance conditions. In the islanding condition, the DR concept is also used. The proposed method is applied to IEEE-RBTS BUS2 standard network and real-world Mahmoud-Abad industrial zone network located in Isfahan, Iran in the presence of DG resources to show its effectiveness. The results are evaluated and compared in different conditions for elucidation.

1. Introduction

In recent years, industrial networks have been so increasingly developed that the assessment of their reliability has become one of the most important issues [1,2]. Also, the use of renewable energy resources has increased due to the limited amount of fossil fuel sources worldwide and the rise of concern over environment. Accordingly, the effects of renewable resources such as wind and photovoltaic on the reliability of industrial networks are highly considered [1–7]. Generally, reliability assessment methods are divided into two categories, analytical methods [8–11] and Monte-Carlo simulation techniques [12–17]. The analytical methods are based on the enumeration of states that are approximate and can be used to assess the expected values of reliability indices. Monte-Carlo simulation techniques are more general compared with the analytical methods. These techniques can provide more information on reliability such as probability distributions of reliability indices in addition to average values. The simulation techniques are divided into two groups of sequential Monte-Carlo

* Corresponding author.
E-mail addresses: sm.nosratabadi@eng.ui.ac.ir (S.M. Nosratabadi), hooshmand_r@yahoo.com, hooshmand_r@eng.ui.ac.ir (R.-A. Hooshmand), e.gholipour@eng.ui.ac.ir (E. Gholipour), rahimi.sadegh@yahoo.com (S. Rahimi).

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[8–10,12,13] and non-sequential Monte-Carlo [8,9,17]. Sequential Monte-Carlo method can simulate the aspects of the system chronologically and determine the duration of interruption due to system failures. For this reason, this method can provide accurate estimations of the reliability indices. But, non-sequential Monte-Carlo method cannot simulate the aspects of the system chronologically [13].

Accordingly, using the analytical methods is useful for the reliability assessment of power systems which are not too big and complex. These methods result in very small calculation errors. But in systems where different situations must be considered or in systems with high number of events taking place, sequential Monte-Carlo simulation method enjoys superiority over analytical ones. This method is used to simulate a performance period of a system (e.g. one year) that is employed with a lot of iterations to obtain statistical indices. Advantages and disadvantages of analytical and sequential Monte-Carlo simulation method are as follows:

1) The time for problem-solving using analytical methods is relatively short, while sequential Monte-Carlo simulation method needs a lot of time to achieve a reasonable answer, although the issue of using modern computers is not important today and can be ignored.
2) Analytical methods always obtain the numerical results from the data derived from a specific input, while the results of the sequential Monte-Carlo simulation is dependent on the producers of random numbers and the number of simulations.
3) The model used in the analytical method is a simplified model of the system that in some cases is very different compared with the main system, while in the sequential Monte-Carlo simulation method, the characteristic of any system with any level of importance could be considered in the problem-solving.
4) The sequential Monte-Carlo simulation method can provide a wide range of parameters such as all real-time probability density functions of the system and components, while the outputs of analytical methods are limited to the mean values.

Based on these explanations and advantages, the sequential Monte-Carlo method should be employed for our proposed method to handle a stochastic procedure on a complex power system with different components.

In general, Distributed Generation (DG) resources include renewable [9,18–21] and non-renewable resources [1–6,8–10,12–14,16–19,22,23]. The proper model (stochastic or deterministic) can be employed depending on the behavior of DG resources. The stochastic model is used to calculate the output of renewable resources such as wind and photovoltaic resources. Also, the deterministic model is used to calculate the output of non-renewable resources such as diesel generators. To assess the reliability of the power networks, wind and photovoltaic renewable resources are used in [5,6].

In recent years, many activities have been accomplished on the distribution level to assess the reliability. In [1], the effect of different types of DG on the reliability of power supply in industrial distribution systems is expressed by permanent and continuous performance, taking into account the non-random behavior of their output. A Monte-Carlo method is introduced to calculate the reliability of the power distribution network in the presence of a random DG [14]. In [13], a state transition sampling method using the non-sequential Monte-Carlo is used for the estimation of the actual frequency index without a need for an additional enumeration. In [24] the Monte-Carlo method is used to assess the reliability of the microgrid in the presence of the DGs and energy storage systems. Ref. [25] is implemented based on enhanced models by which an incentive-based Demand Response (DR) program is investigated and a dynamic price elasticity of demand is considered to be added to the flexibility of demand response programs in a probabilistic day-ahead operational scheduling. This method prevents computational intractability while considers uncertain nature of generation unit failures. In [26] the taxonomy of active network management schemes and models applied to the optimal operation of smart distribution network as well as the classification of algorithms and methods for the optimal operation of smart distribution network, and recommendations and trends for future research in the field of optimal operation of smart distribution network are considered. In [27], a procedure to calculate the flexible reliability and overall reliability is introduced and some indices are defined to show the overall reliability and flexible reliability levels of the hybrid AC–DC microgrid. Then, a sensitivity analysis is carried out to indicate the impacts of increasing the capacity of each Distributed Energy Resource (DER) technology on the overall reliability and flexible reliability indices of the microgrid. To perform the sensitivity analysis, the capacity of one DER technology is increased while the capacity of the other DER technologies remain constant and the amount of variation in overall reliability and flexible reliability indices of the microgrid are calculated. The taxonomy of state-of-the-art power distribution planning models and methods offering a unifying description of a relatively large number of works devoted to the subject are introduced in [28]. Moreover, this work analyzes and classifies the current and future research trends in power distribution planning. This review aims to serve as a guide to power system engineers and researchers on the available power distribution planning models and methods in the modern power systems era.

In [29], a new probabilistic index is defined by combining the two aspects with regard to the importance of both reliability and supply-adequacy of microgrids. Afterwards, two systematic approaches are presented for optimal construction of microgrids in a distribution system. In the first scenario, the microgrids are designed after optimal allocation of DGs and in the second, the microgrid design and DGs allocation are performed simultaneously. In [30], an efficacious approach is proposed to achieve accurate reliability indices while considering state-of-the-art technical level of microgrid protection. The proposed method utilizes a short-term outage model that quantifies the relationship between state variables and the outage rate of the components. A hybrid approach is proposed which combines scenario selection and enumerative analysis. Ref. [31] presents a framework to quantify the reliability benefits of activating DR potentials with direct and indirect benefits to electricity service reliability. DR allows network operators to alleviate operational limit violations in place of load shedding