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Weibull distribution-based analysis for reliability assessment of an isolated power micro-grid system

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Abstract

This study investigates Weibull Distribution-based Analysis for reliability assessment of an isolated power Micro-grid system. The Mean Time to Repair (MTTR) reliability indices were calculated using the outage data obtained from the micro-grid site between 2015 and 2019. The Weibull probability function is widely used in reliability analysis; in this method, the shape and scale parameters were calculated using the Maximum likelihood Estimator (MLE). MLE technique was deployed to check the problem of the MTTR data analysis from data collected to estimate the Weibull study. The research involved the percentage, cumulative percentage, density, cumulative probability,

survival probability, and hazard probability. The scale parameter, which was observed as 0.625195, equally represents the mean failure time of 0.99728, which influenced the overall reliability performance of the micro-grid power system.

Introduction

Deficient electricity supply has always been a long-term issue in Nigeria and has led to low development. From statistics, over 2 billion people do not have access to the power supply in most regions of Nigeria [1]. With the world striving to achieve the 7th goal of Sustainable Development Goals (SDGs), the SDG goals of affordable and clean energy, the Nigerian government is also deploying stand-alone micro-grid to rural locations. But these micro-grids are expected to be reliable to meet the increasing energy demand of the rural dwellers [2]. Hence reliability analysis needs to be carried out on these micro-grids to ensure availability and sustainability. A Physicist named Weibull from Sweden introduced the Weibull distribution. Weibull distribution has been applied in several areas such as engineering, medicine, material science, chemistry, physics, geography, business, and metrological regions [3]. Power systems and the reliability of their components are usually carried out using reliability analysis. The process involves reliability modeling, data collection and processing, and the reliability evaluation of the components and system [4]. Several indices representing the reliability measures are defined, and some of these indices are later calculated for quantitative reliability analysis. All the measurements of reliability quantify the future behavior of power system units[5], [6]. On the other hand, reliability indices and analysis depend on the applications, operating conditions, failure types, etc. Reliability indices can be used to express results from a reliability study; hence, several reliability indices are used for reliability evaluation that is sometimes interdependent. The authors in [7] carried out a reliability analysis of a micro-grid, but the meantime to repair (MTTR) of components was not considered. Ansari et al., [8] presented a wind and solar energy micro-grid reliability assessment and observed that wind and solar energy's stochastic design adds uncertainty to the power system. State sampling simulation was used to deal with the stochastic existence of the energy resources, while reliability measurements were done using analytical methods. The islanding reliability operation was also observed to decrease with a decrease in the system's reliability, but MTTR was not considered. In [9], ways of higher reliability achievement for a stand-alone hybrid system were evaluated. Assessment of reliability indices of a micro-grid system with a micro gas turbine (MGT) was done applying Monte Carlo Simulation. [10]. The gap in the literature is that most previous researchers did not use Weibull analysis in their reliability analysis to reflect the effect of MTTR on a power micro-grid. Secondly, most problems did not use Statgraphics Centurion 18 version statistical tool to analyze a micro-grid system's reliability. Hence to fill these gaps, this paper has to investigate the stand-alone micro-grid using MLE in the Weibull analysis.

Challenges related to blackouts and brownouts require a new concept of power supply systems such as micro-grid for a reliable power system. Micro-grids are localized clusters of electric supply generation, energy backup storage, and various loads that are usually connected to a conventional national grid (Macro Grid) or off-grid [11]. Micro-grid can make power supply efficient and economical with features that make the power system very attractive [12], [13]. Micro-grid components could constitute various

distributed energy resources (solar photovoltaic, small wind generators, fuel cells, diesel generators, micro-turbines, etc.) and backup devices[14]. One or more conventional energy sources, such as diesel, could also be added to the system to function as an alternative power source due to the variability of renewable energy sources [15], [16]. Micro-grid is seen in Africa as nearly the next alternative for rural electrification due to the benefit of its position in the equator. Ref [17], noted in their study of micro-grid penetration in the tropical region such as Indonesia, with an abundance of Solar PV potentials, electrifying these tropical countries will decarbonize rural communities. Hence investigation of micro-grid is necessary for the development of the power system network in Africa [18].

Section snippets

Methodology

Some methods of Micro-grid reliability have been presented by several authors considering customer load points. These methods include analytical (systematic) and simulation. However, in this paper, Weibull distribution-based analysis was considered. Historical data were collected from the Micro-grid site for five years, from 2015 to 2019, and deployed to compute the reliability indices. The primary data collected for 2015, used to calculate the reliability index, is presented in Table 1.

Results and discussion

Table 2 summarizes the result of the reliability indices that were analyzed. Values from Table 2 were used as input for the Statgraphics Centurion 18 version, thereby yielding Table 3, which shows the Weibull parameters as analyzed using the Statgraphics Centurion 18 version, a statistical tool for analyzing the reliability of failure data. All parameters displayed were selected based on the theory of the maximum likelihood estimation (MLE) approach. MLE technique was deployed to check the

Conclusions

The study analyzed a stand-alone micro-grid using the Maximum likelihood Estimator of Weibull distribution. Evaluation of the Weibull parameters for a period of five years was presented in this paper. The percentage and density distribution of the MTTR data shape reflects a right-skewed pattern that implies the MTTR data's real-life distribution. Thus, the usefulness of the distribution was demonstrated. More so, it was observed that the variability in the survival and hazard functions could be

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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