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Original article

Efficiency evaluation of the microgrid for selection of common bus using copula function-based efficiency curves of the converters

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ABSTRACT

Due to the increase in load growth, construction of renewable energy-based microgrids (MG) has been seen as the most economical and viable solution in the recent past. It leads to the need for feasibility investigation at the planning and design stage for appropriate selection of common bus (CB) type. One of the critical factors to determine the suitable CB is efficiency analysis. This paper proposes an efficiency evaluation method by using the copula function-based efficiency curves of the converters. The degree of association between percentage loading and efficiency of the converters is defined using best-fitted copula estimation, and a large number of iterations are performed using Monte Carlo simulations to generate the efficiency for each time instant. A variety of scenarios are simulated to determine when and which type of CB is most favourable. The efficiency of the MG is strongly dependent on the converter efficiency, number of converters in the MG, and seasonal variations, both in generation and load demand. The results indicate that DC CB has superior performance with the net efficiency gain ranging from 8.26% to 5.63% in all scenarios considered in this study. Moreover, DC CB is most advantageous in the MG with the DC load only. It will bring greater advantages in the future with the continuous development of renewable energy-based MGs and the increasing penetration of DC loads.

Introduction

Energy demand in the world continues to rise at an alarming rate. The International Energy Outlook 2019 (IEO2019) projects a 50% increase in global energy consumption between 2015 and 2040. Moreover, governments have been encouraging to reduce greenhouse gas emissions (GHG) [1]. Thereby, renewable energy-based microgrids (MG) construction with on-site generation and local utilization has shown a significant surge in the past few years [2,3]. MGs are energy providers that can reduce energy expenses and emissions by utilizing distributed energy resources (DERs) and eliminating the need for high-capacity transmission lines. Among various DERs, renewable energy resources (RERs) play an essential role in providing a sustainable energy supply infrastructure, as they are both inexhaustible and non-polluting. Furthermore, DERs are also comprised of energy storage systems (ESS) to account for the intermittent nature and the uncertainties associated with RERs. Besides this, MGs are also connected to the utility grid (UG) to improve the reliability of the system.

Inside the MG, the DERs, load, and UG are connected at the common bus (CB) through suitable power electronic (PE) interfaces. The CB is the backbone of MG that circulates the power among its components. Whether it is AC or DC, CB's nature defines the type of MG [4]. Categorically, selecting the right kind of CB defines the number of conversion stages and the associated cost of power converters, losses inside the MG, ease of integration of various DERs, need for synchronizing generators and control system's complexity level etc. [5]. Therefore, the feasibility analysis of an appropriate type of CB at the early design stage is the need of the hour to improve the design performance significantly. The feasibility criterion requires several factors to be considered for design optimization, e.g., economic analysis, efficiency analysis, reliability analysis, etc. This paper emphasizes on the efficiency evaluation of MG as a decisive factor to prove the dominance of one over the other.

Being the cornerstone of distribution systems, the efficiency of MGs mainly depends on PE converters' efficiency. The authors compared the low voltage AC and DC distribution systems concerning the number of required conversion steps by assuming that each conversion stage loses about 2.5% of the energy it converts. However, the impact of load variation on converter efficiency was not considered [6]. Another loss comparison was made for the two paradigms in Starke et al. [7]. Nevertheless, the authors assumed that the efficiency of the converter is fixed under all operating conditions. Sannino et al. [8] carried out a

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