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Assessing the Effectiveness of Weighted Information Gap Decision Theory Integrated with Energy Management Systems for Isolated Microgrids

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***Abstract*— In the context of microgrid, renewable energy variations are still a major concern for operators, especially in industrial applications in which microgrids are typically located in remote areas and are operated autonomously. Information Gap Decision Theory (IGDT) is a non-probabilistic method utilized to appraise various levels of risk without the availability of statistical data, such as probability density functions of uncertain parameters. Despite such a rewarding feature, the IGDT in its current form is unable to obtain time-varying robustness bands, meaning that it does not take into consideration the system risk imposed by renewable energy injections at each individual time interval in a short-term operation horizon. To overcome this issue, this paper presents a modified version of the IGDT named Weighted Information Gap Decision Theory (W-IGDT), yielding risk-based time-varying robustness bands rather than time-independent ones. This paper also proposes a W-IGDT-based Energy Management System (EMS) based on a linked Unit Commitment-Optimal Power Flow (UC-OPF) framework, which simultaneously incorporates the generating units on/off status as well as power flow limits into the optimization procedure. In order to illustrate the performance of the proposed EMS, a CIGRE microgrid benchmark is utilized, and the results indicate the effectiveness of the W-IGDT-based EMS in terms of optimal operation and addressing the intermittency of renewable energy sources.**

***Index Terms*—Energy Management System (EMS), microgrid, optimal power flow, unit commitment, Weighted Information Gap Decision Theory (W-IGDT), wind power uncertainty.**

I. Introduction

A. Background and Motivation

MICROGRIDS have been constantly developing since they are very promising for electric energy industry with the integration of Renewable Energy Sources (RESs) due to many advantages, such as reducing environmental impacts, improving reliability, and significant cost saving through the integration of microsources, which reduces transmission and distribution system costs [1], [2]. Microgrids can operate in two different modes: grid-connected and islanded. In the grid-connected mode, the microgrid has interconnection with the host power system at the Point of Common Coupling (PCC) at a distribution level, being supported by the main grid to supply any potential power deficit or to provide ancillary services with excess power generation within the defined microgrid boundaries. In contrast, in the islanded mode, which is mainly occurred due to maintenance, up-stream network's power quality issues, and unexpected faults, the total power generation and loads should always be balanced locally to maintain the voltage and frequency stability. Nevertheless, there exist a number of remote communities which have no any interconnection with the main grid owing to economical and/or technical hurdles, resulting in operating permanently in the off-grid mode, referred to as "isolated microgrids" [3]–[5]. There are certain challenges that should be carefully understood and addressed to better manage and operate isolated microgrids, including appropriate planning of generation and storage units with respect to load demand on a short term basis, ensuring the economic operation using Economic Dispatch (ED), Unit Commitment (UC), and Optimal Power Flow (OPF) methodologies, and maintaining the security of system through emergency conditions, including shut-down of generating units or power drop of RESs due to their intermittent behavior [6]. These challenges are typically supposed to be addressed by the microgrid controller. Energy Management System (EMS) shoulders the responsibility for optimal dispatching of different Distributed Energy Resources (DERs), considering technical constraints and the uncertainty of RESs. Developing an EMS, therefore, to address these challenges is of great significance for utilities and industries, active in the microgrid field.

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B. Literature Review

1) Microgrid EMS: There are several studies regarding the microgrid operation and control in the existing literature. One particularly salient example is [7], where the authors take advantage of neural networks in order to design their EMS. In this work, fully connected Neuron Networks are combined with the OPF methodology to shorten the time of simulation. Nonetheless, the on/off status of generating units are not considered in this work. Another instance is [8], where the authors intend to design an EMS based on the UC and OPF architectures for a big microgrid, with multiple busbars. In this paper, the UC and OPF methodologies are solved non-simultaneously using a decomposition approach to decrease the computational burden. Indeed, authors, at first, assume that all generators and loads are connected to one busbar, determining the UC decisions. Subsequently, considering these UC decisions, they intend to factor in the OPF methodology, separately, with a linear approximation