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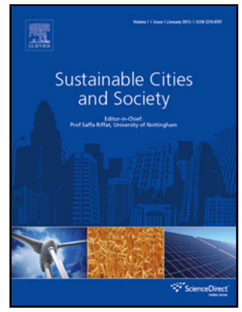

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Risk Analysis and Self-Healing Approach for Resilient Interconnect Micro Energy Grids

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Abstract

Micro energy grids (MEG) have been proposed to fulfil the concurrent expansion of electrical, cooling and heating energy distribution systems, without taking in consideration safety performance indices. This study is concern on risk analysis of micro energy grids (MEG) with corresponding uncertainties in electrical, cooling and thermal demands; further to the impact of PV and wind power productions intermittency. Several contributions are presented in this paper, such as: developed hazard matrix of MEG, developed two approaches of risk assessment, i.e. fault tree analysis and layer of protection analysis (LOPA), and finally proposed a solution to prevent and mitigate the hazard impacts by offering a resilient MEG configuration model. This model consists of an enhanced independent protection layers (IPL)s, i.e. Co-generation, thermal energy storage (TES) and multi-level hierarchical control. The performance of the proposed configuration model has proven that it reduces the influence of the renewable sources intermittency and also increases the MEG production capacity. Also the proposed model shows a robust self-healing capability, to meet on-demand load requirements, under different hazardous scenarios. Further to achieve the simultaneous goals of increasing the energy efficiency, reducing gases emission and improve sustainable economics.

Keywords: *Micro Energy Grid (MEG); Fault tree analysis; Layer of protection analysis (LOPA); Independent Protection Layers (IPL); Resiliency, Reliability, Fuzzy Control system; Hierarchical Control System; Fault Tolerant Control.*

1. Introduction

With the increasing concerns regarding energy reliability and emissions, the claim on self-generation and distributed energy resources (DER)s are increasing accordingly. Two-thirds of all fuel used to produce power electricity is mostly wasted by emitting unused thermal energy from power generation system into the air or into water streams (e.g. sea and river). The average efficiency of power generation has remained around 33 percent since 1960. A combination of electric power generators, district cooling/heating units, energy storage devices, and renewable energy sources are widely deployed to meet the energy demands of electrical, cooling and heating for several types of buildings [1]. This combination is commonly named micro energy grid (MEG). MEG can increase the overall energy efficiency of an energy system further to provide environment benefits by reducing primary energy consumption and related greenhouse gas emissions [2]. These systems can upsurge the energy efficiency up to 90 percent, by utilizing thermal energy produced as a by-product of power generation for cooling, heating, and humidity control systems [3][4]. Thus, implementing of such a large complex system with uncertainty of dealing with various unknown parameters is increasing the hazardous condition [5]. Consequently, the hazard analysis is a critical part of system safety design. Where safety design of MEG having higher fault tolerance ability against various types of risks events and hazardous scenarios is paramount for resilient MEG. The resilient MEG is a small or medium scale autonomous energy supply system which is merged of smart meters and sensors, automated controls and advanced software. The advanced software employs a real-time