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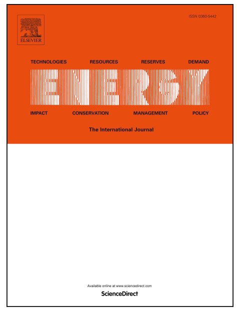

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Customer domain supply and load coordination: A case for smart villages and transactive control in rural off-grid microgrids

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Abstract

Global humanitarian initiatives are calling for technologies to bridge the urban-rural divide in support of remote community electrification projects through micro-utility programs. Distributed off-grid renewable generation has the ability to supply energy to remote communities while smart microgrids are able to effectively integrate intermittent renewable resources through management procedures that improve reliability, resiliency and sustainability. Microgrid control systems are typified by a hierarchical nature with multi-layered functionalities and capabilities to ensure optimized operations through strategic energy management and power flow balancing. This paper considers transactive energy management principles for supply/demand coordination and demonstrates that the concept is effective in managing energy demand response and data flow dynamics in the context of rural community-based energy systems. A transactive energy management system is modeled for rural village DC microgrids, and evaluated through demonstrative computer simulations. It shows how smart microgrid load control switching on homogeneous load groups is commanded through microgrid economic value signals that are adjustable by home owners to meet village and household energy budget constraints. The proposed approach is novel in that it offers a low complexity coordination framework, based on market principles, and demand response mechanisms for multi-priority grouping control of non-intelligent devices in off-grid rural village settings.

Keywords: Smart Village, Transactive Energy, Central Numerical Optimization, Transactive Optimization, Rural Electrification, Autonomous Transactive Operation, Smartgrid Coordination.

1. Introduction

Significant efforts have been made to bring clean and reliable energy to over a billion people who live in isolated rural areas across the world [1]. While access to sustainable electricity plays a key role in poverty alleviation and economic development, it is also considered a basic human right and many governments in developing countries are under pressure to meet these development goals [2][3][4]. According to the International Energy Agency (IEA), about 84% of people without electricity live in remote rural areas where the population density and energy demand is low [5]. It is not always cost effective to expand the national grid infrastructure to these rural areas because of their low rate of energy consumption and high infrastructure and maintenance costs, factors that make stand-alone off-grid systems an attractive solution [6][7].

In recent years the unpredictability of fossil fuel costs, coupled with significant reductions of renewable energy technology costs, have encouraged a wider adoption of microgrids powered by renewable distributed energy resources [8][9]. Compared to the expansion of legacy power generation and distribution systems, microgrids are considered to be the future of power system dispatch and storage configurations since they provide clear economic and environmental benefits [10]. Remote microgrids currently account for over 50% of the total installed microgrids worldwide and show a strong potential for electrifying rural villages and off-grid island communities [11][12].

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