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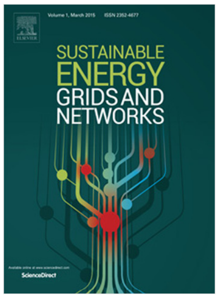

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Composition, Placement, and Economics of Rural Microgrids for Ensuring Sustainable Development

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Abstract — **Nearly 20% of the world's population does not have adequate access to reliable - or any - electricity, and population growth is exceeding electrification rates. The desire for power in rural and developing communities is growing continuously, and access to electricity can now be considered a necessity, not an extravagance. Lack of electrification contributes to cyclic poverty, child mortality, and hampers education, leading to an even greater divide between the developed and developing worlds. Centralized generation and distribution systems are not suited to rural areas where transmission distances are great, nor developing areas where the capital cost of large centralized generation plants is untenable. This work examines the practicality of energy production and storage, covering a large portion of the globe utilizing HOMER as an optimization tool. Multiple load profiles based on actual developing rural usage were used to create a variety of community scenarios, and the demand was optimized with a variety of generation and storage options. Every model utilizes location-based radiance, wind, and fuel prices. The goal of developing electrification is twofold: First, to provide affordable and reliable electricity, and the second is to explore every avenue of generating that electricity in an environmentally sustainable way. The sites represented in the paper one from each country signify communities in various states of development based on an earnings metric. Ultimately, the relative power of irradiance, wind speeds, and diesel prices can be compiled into a single index to determine whether a community should tie into the grid, or have a standalone microgrid. This break-even point from an economic standpoint is short, and favors independent microgrids in many rural areas. Additionally, whether a community should consider completely renewable energy, or mixed renewable and diesel generation sources is highly predictable based on only a few metrics, and in many circumstances, makes little impact to the levelized cost of energy.**

Keywords — Microgrids, Grid Extension, Distributed Generation, Energy Storage

I. Introduction

As countries shift towards increasing the renewable capacity on their national grids, their use in smaller independent grid systems becomes increasingly critical. Whenever new options are presented, entire systems must be reevaluated, and grid extension techniques in a developed urban environment are often not the correct options for rural communities. Far-reaching national grids are generally exorbitantly expensive for underdeveloped governments and their utilities, and are not cost effective for thinly populated areas where demand will not cover extension costs [1, 2].

As distributed generation (DG) microgrids become more feasible, the associated challenges in control, management, and integration must be addressed. DG microgrid operations differ seriously from conventional electrification schemes, and with infrastructure generally new, techniques such as demand-side management [3,4] and load scheduling [5,6] have been employed to increase the efficiency and viability of microgrids. Since microgrids are by nature small, power schemes from renewables or small diesel generation are the most sought after [7–9]. However, because of renewable indeterminacy, storage options have been widely explored [5, 7, 9–12], and have shown to improve the viability of DG microgrids and lower the levelized cost of energy (LCOE). Furthermore, because microgrids can generate from and distribute to multiple points - and these can change as loads and generation comes on and off line - integration plans are required [4, 13–15]. Another serious focus of microgrid viability has centered around droop control [15-21]. As generation and demand vary throughout the day, the local frequencies can fall outside of the acceptable tolerances, and without proper inverter control, will bring the microgrid down.

This research area focus has not often centered on rural and developing-world electrification, although specific case studies in Asia and parts of Africa have proven the localized feasibility [21–25], much remains to be done about rural microgrid placement techniques. One of the major issues addressed in this work focuses on large-scale deployment of small-scale systems in an efficient manner. Much of the previous work focuses on the effects and efficiencies on a single system, and are often standalone. Few studies have examined rural demand growth and current government and NGO electrification schemes, and have analyzed the performance and thus feasibility of rural electrification [8, 22]. Additionally, while much of the work surrounding microgrids focuses on optimization or advances in specific technologies, little has been done to address the issue of location suitability or national grid substitution. Usually two states for microgrid use exist: it is either assumed that the