Microgrid development apia

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This paper reviews practical challenges for microgrid electrification projects in low- and middle-income economies, proposing a Social-Technical-Economic-Political (STEP) framework. With our STEP framework, we review recent Artificial Intelligence (AI) methods capable of accelerating microgrid adoption in developing economies.

Many authors have employed novel AI methods in microgrid applications including to support energy management systems, fault detection, generation sizing, and load forecasting. Despite these research initiatives, limited works have investigated the specific challenges for developing economies. That is, high-income countries often have high-quality power, reliable wireless communication infrastructure, and greater access to equipment and technical skills. Accordingly, there are numerous opportunities for the adaptation of AI methods to meet the constraints of developing economies.

In this paper, we provide a comprehensive review of the electrification challenges in developing economies alongside an assessment of novel AI approaches for microgrid applications. We also identify emerging opportunities for AI research in the context of developing economies and our proposed STEP framework.

This paper aims to holistically examine AI solutions and their integration within emerging economies, bridging the gap between academic scholarship and real-world contexts. To our knowledge, this paper represents the first such type of review with the analysis of AI applications in microgrids with a specific focus on the limitations inherent in low- and middle-income countries. The chief objectives of this review are

To provide insights into the social, technical, economic, and political (STEP) rural electrification challenges unique to developing economies,

Access to electricity has been associated with numerous developmental and welfare benefits, such as increased economic opportunities, better quality of life, improved health, and greater educational attainment [20,21,22]. Renewable energy electrification in regions without electricity can yield additional social benefits. Electrification could introduce awareness and opportunities for refrigeration, proper lighting, and electrical based clean cooking, which can all improve the quality of life [23,24,25].

In efforts to improve both reliability and electricity access, microgrids are often suggested as an innovative and cost-effective solution [29]. A microgrid is a localized grouping of electricity generators and electrical loads capable of operating independently of the centralized grid. Depending upon the connection with the main grid structure, microgrids can take on two forms--grid-connected or islanded (standalone) [30].

A grid-connected microgrid aims to enhance reliability, reduce transmission demands, and provide an alternative power source during instances of large-scale outages by disconnecting autonomously from the main grid structure. On the other end of the spectrum is the islanded microgrid, which are self-sustaining, standalone entities supplying electricity without any connection to the main grid. Islanded microgrids are especially relevant in the context of rural electrification of regions already devoid of grid power.

The drive to extend electricity services to rural regions in developing economies has been a longstanding initiative by the UN, the World Bank, non-profit organizations, and governments worldwide [13, 19, 32]. Despite the significant interest in electrification, electrification rates have progressed slowly, with many projects failing due to social, technical, economic, or political challenges that were not adequately addressed [33, 34].

In this section, we examine and identify four key pillars reflecting challenges in developing economies. It is important to keep in mind that these pillars are often heavily codependent and can be segmented into a variety of subsequent challenges. The categories, as represented in Fig. 2, are social, technical, economic, and political (STEP). Through an understanding of the STEP challenges, we provide a foundation for identifying and implementing effective strategies for accelerating electricity access in remote regions.

The success of an electrification project often hinges on the involvement of all stakeholders from the outset--from local communities to developers and governmental organizations [7oo, 35]. Cultural and behavioral differences oftentimes serve as barriers to electrification as they may incur significant societal and cultural change [36].

Contrary to the general optimism around renewable energy''s role in facilitating electricity accessibility, awareness lags significantly. For example, in Nigeria, nearly 40% of the population is unaware of the potential for solar photovoltaic systems [40]. Focusing on grassroots-level education, targeting women (often traditionally in charge of household energy management) can enable a smoother transition to modern energy systems [41].

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