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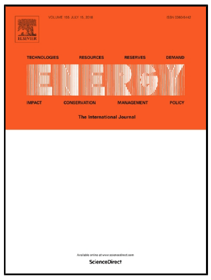

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MODELLING OF AN EXPANDABLE, RECONFIGURABLE, RENEWABLE DC MICROGRID FOR OFF-GRID COMMUNITIES

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Abstract

This paper proposes a DC microgrid system, comprising multiple locally available renewable energy sources in an off-grid rural community, based on a commissioned field study carried out in a rural, off-grid village in Nepal, which has solar and wind resource available. Using estimated solar data for the site's location, wind data measured locally, household and population data collected over the course of several months and typical measured domestic demand profiles, DC microgrid system models have been constructed using HOMER and Simulink software to represent the DC system proposed.

This work is innovative in using a range of on-site data collected and measured locally in a commissioned field study carried out over several months to quantify current local resources and loads and estimating future ones based on the local population's current economic and domestic activites, and intended ones. This data is used in determining both the optimal size of the generation and storage elements through HOMER based on long term system behaviour, and to model shorter term system response to changes in generation and load using Simulink, ensuring system stability and grid voltage is maintained. Further novel aspects of this study are that power flow is controlled using adaptive DC droop control on each individual energy source to enable optimal power sharing with minimum power dissipation across distribution lines, and the droop control has been further adapted to the case of storage which can act as a source or a load.

Keywords: DC microgrid, DC non-linear droop control, Solar, Wind

1. INTRODUCTION

Of the 1.2 billion people who do not have access to electricity, nearly 85% are in rural areas [1], and most of these will require off-grid solutions to achieve the U.N.'s goal of universal energy access by 2030 [2]. For these solutions, renewable generation technologies are often the most appropriate, as they are sustainable and allow local power generation without any requirement for external energy supply. Off-grid renewable solutions are normally on an individual household scale, such as the Solar-Home System (SHS), or community scale solutions, where a single resource powers multiple households such as a micro-hydro scheme. Microgrids have emerged as an opportunity to connect multiple sources and loads that are in close geographic proximity, and can be either grid-connected or islanded.

Both AC- and DC-based microgrids have been investigated [3], with benefits and drawbacks to each type of system. AC networks are often implemented, as they replicate the standard electrical distribution system, with their technology understood, able to change voltage levels simply to transmit longer distances, and a well-developed supply chain of end-use equipment However, DC microgrids have advantages of simpler control with no requirement for synchronisation, and are able to integrate renewable sources such as photovoltaics and battery storage easier than AC networks, can produce systems with lower losses due to the ability to dispense with AC-DC power conversion and as such are being increasingly investigated [4], [5]. Primary control for DC microgrids can be based on droop mechanisms, where the output voltage of a source reduces as the power demand increases, mimicking grid attributes [3]. This can be achieved artificially through power electronic interfaces so that power flow can be balanced autonomously between sources without central control, with further levels of control added as required [6]. Additional control levels can be included in the grid system, to support