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Economic rationalization of energy storage under low load diesel application

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Abstract

Globally diesel generator sets account for the majority of generation into remote and off-grid power systems. While diesel generation has proven to be a reliable and accessible technology, its downside involves the expense and environmentally emissions linked to diesel fuel consumption. In response diesel generation alternatives are becoming available and cost competitive, via the integration of renewable energy technology (RET). Hybrid power systems (HPS), those adopting both diesel and RET are increasingly employed to reduce cost and environmental emissions. As RET penetration increases within HPS a potential conflict arises, with diesel generation unable to lower output below minimum load set points. These load set points are predetermined to ensure engine efficiency and reliability. Under medium to high renewable penetration, diesel load set points compete with renewable generation to produce surplus energy. This surplus energy must be absorbed by the system. Various ancillary technologies, such as demand management, energy storage and dump loads can perform this role; however such technologies are expensive and complex. This paper introduces low load diesel (LLD) as one solution to minimising surplus generation within HPS. Economic and power modelling is used to explore removal of energy storage (ES) under LLD application. Model validation, undertaken against both kW and MW scale operational diesel generator data sets is referenced to support the conclusion, that LLD is cable of reducing both system establishment and operational costs for medium to high RET penetration HPS.

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Keywords: Hybrid power systems; low load diesel; variable speed diesel; remote area power; energy storage systems.

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1. Introduction

Renewable energy technology (RET) is becoming increasingly relevant to off-grid communities as they seek to reconfigure their power supply away from reliance on conventional diesel generation (CDG) [1]. While CDG has served these communities for decades, escalating costs, and an awareness of the environmental and health issues resultant from diesel combustion justify change [2]. RET integration offers some relief to these communities. Firstly it offers relief from the high operating expense (OPEX) of CDG [3]. RET costs in contrast are principally linked to the initial RET purchase and integration, or capital expense (CAPEX). Development of RET projects can accordingly be characterised as high CAPEX, low OPEX activities. While CDG is a low CAPEX, high OPEX undertaking. Both have advantages, with CDG the more expensive option, yet able to defer much of its cost to future years. Indeed total lifetime costs (CAPEX plus OPEX) of CDG often exceed that of RET many times over [4]. Importantly, RET integration also offers immediate environmental and health benefits [5], with reduced diesel fuel consumption responsible for lower emissions and waste. While CDG remains the primary source of generation into remote communities globally, increasing awareness of both the total lifetime costs and environmental damage, increasingly promote the integration of RET's.

While HPS offer consumers many benefits over CDG, the stochastic nature of many RET's creates issues, the complexity of which increases with RET penetration [6]. For low levels of RET penetration (0-30%), few issues are observed. For medium and high levels of RET penetration (>30%), additional ancillary technology integration may be required. Energy storage (ES) integration is one common approach, with system requirements determined by the level of RET penetration. ES permits higher levels RET integration, albeit at the cost of additional system complexity and cost. Figure 1 illustrates the increasing costs associated with RET integration for a grid connected microgrid [7]. Initially RET integration is shown to lower the cost of generation (note the cost reduction is many times greater for off-grid systems given the higher base cost of CDG). While RET cost/benefit is optimal for medium and high levels of penetration, the majority of HPS restrict RET penetration to <20%, possibly to limit system complexity. Wholly RET supplied HPS would return maximum environmental benefit, eliminating the need for CDG entirely, however such "diesel off" systems are neither economical nor simple.

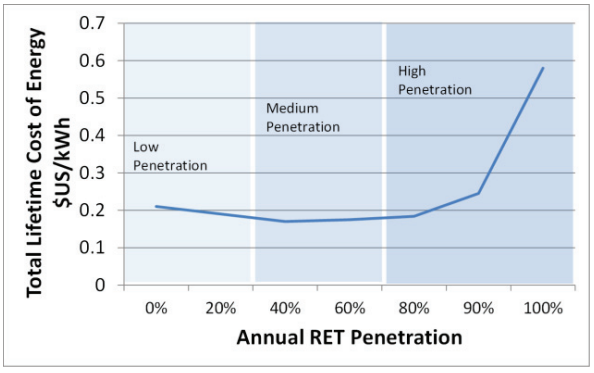

Fig. 1. RET in microgrids. [7]

Low Load Diesel (LLD) offers one solution [8], preserving the simple system architecture of low penetration HPS, yet permitting medium to high levels of RET penetration. The lower you can operate diesel generators, the greater RET penetration you can accept, and the lower your generation costs [9]. Historically, prolonged low load operation was ill advised, contributing to cylinder glazing, wet stacking and eventual engine damage [10], however a range of modern diesel technologies have silently eroded many of these barriers [11].

Prior research has investigated many of the problems caused by high RET penetration in HPS [12, 13]. The opportunity to replace CDG with wind generation has also been widely discussed [14]. Isolated power system control strategy, which can be categorized by control technique, and energy management strategy represents another body of existing research [15-17], with much of this research directed to optimal ES sizing. In [18] a power sharing approach