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Optimal integrated diesel grid-renewable energy system for hot water devices

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Abstract

Many remote areas in developing countries such as Africa and island developing nations rely on expensive diesel grid even though there is a high potential for renewable sources such as wind and solar. Further, in domestic houses, water heating contributes to a huge percentage of the overall electricity consumption. Therefore, integration of renewable energy and efficient water heating systems would lower the electricity cost and greenhouse gas emissions. This paper introduces an optimal control model for a hybrid heat pump and instantaneous water heaters powered using integrated energy systems. The model can lead to 5.5% of power-not-delivered and 24% water savings.

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Keywords: Optimal; Wind; Solar; Diesel; Grid.

1. Introduction

Many countries in the world are steadily adopting renewable energy while reducing over-reliance on fossil fuels. However, remote areas in many developing nations, such as Africa and most islands developing nations, are still using fossil fuel generators [1]. The negative environmental effect of the fossil fuels, coupled with high fuel importation transport cost and diseconomies of scale in electricity production lead to exorbitantly high energy cost and long term financial risks for the economy [2]. Furthermore, the increasing population in these developing nations is straining the existing energy

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infrastructure through the increasing energy demand. Renewable energy technologies are a sustainable solution to providing cheaper and cleaner energy in these areas. For instance, in Maldives islands, integrated solar and wind electricity generation systems have been proven to be financially feasible for supplementing the fossil fuel based generators [3]. Although hybrid renewable energy systems are being adopted, one of the challenges is to design an optimal energy management system that satisfies the load while considering the intermittent nature of these renewable energy sources and variations in power demand [4].

In buildings, about 23.60% and 60.51% of energy is used for water and space heating respectively. Energy and water efficient technologies are indeed necessary to reduce the consumption of these resources at buildings level [5]. Heat pump water heaters (HPWHs) can reduce the amount of energy consumed in water heating if optimally connected with distributed renewable energy resources. Unlike storage water heaters, HPWHs operate on the principle of the refrigerant cycle converting one unit of electrical energy to produce three units of thermal energy [6]. Various studies have looked at ways of efficiently using HPWHs [7][8][9]. Even though HPWHs have a high coefficient of performance than other water heating technologies, they have a slow rate of heating the water. Consequently, in instances where there is high demand for hot water, HPWHs are unable to supply it. Another drawback is the energy and water losses associated with the hot water conveyance up to the consumption point [10]. To mitigate these losses, instant water heaters placed at the consumption point can be used.

This paper introduces an optimal model that minimizes both the energy and water consumption by using HPWH and instant heater to conveniently meet the hot water demand. The model uses an integrated wind, solar and diesel generator. Therefore, the use of diesel grid and instant shower is optimally minimized. Further, the excess energy from the renewable sources is fed back to the grid through an appropriate feed-in tariff.

2. Model formulation

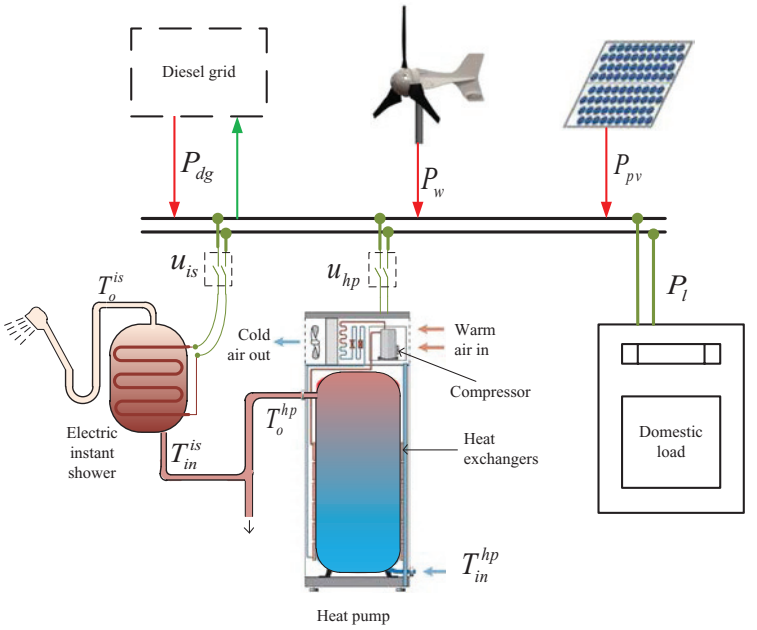

Fig 1: Schematic layout of the energy and hot water flow