Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 105 (2017) 2151 – 2156

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

# Optimal operation of integrated heat pump-instant water heaters with renewable energy

Evan M. Wanjiru*[1], Sam M. Sichilalu[2], Xiaohua Xia[1]

[1]Centre of New Energy Systems, Department of Electrical, Electronic and Computer Engineering, University of Pretoria, Pretoria 0002, South Africa

[2]Faculty of engineering, Mosi-O-Tunya Unversity of Science and Technology, Lusaka, Zambia

**Abstract**

Developing nations such as South Africa are energy insecure despite their high potential for renewable energy sources such as solar. This has forced various governments to initiate energy efficiency and conservation programs. Water heating contributes to a significant percentage of the electricity consumption in domestic and office buildings. Therefore, integration of efficient water heating systems and renewable energy would ensure energy efficiency in these buildings hence lowering the electricity cost and greenhouse gas emissions. This paper introduces an optimal control strategy for heat pump and instant water heaters powered using integrated energy systems. The control strategy can lead to 35% of power-not-delivered, 7.5 kWh energy sold back to the grid while lowering the energy cost by about 19% in a day.


Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

*Keywords:* optimal control; energy efficiency; solar; heat pump water heater; instant water heater.

## 1. Introduction

The world, particularly the developing nations are facing increased energy demand as a consequence of increasing population, urbanization and improved living standards. For instance, Eskom, South Africa's power utility, has in the recent past been unable to meet the energy demand. This has led to widespread black outs (load shedding) [1], causing economic losses to the tune of US$ 7.2 billion per month [2]. Lebanon meets most of her energy needs from oil imports while the deficit is compensated through many small backup generators [3]. Africa's largest economy, Nigeria, has low connectivity and poor grid quality forcing many homes and businesses to use small generators to meet their energy needs [4]. In addition, Pakistan's electricity supply is 25-50% short of demand leading to load shedding of up to 12 and 20 hours and urban and rural areas respectively [5]. Various governments are therefore implementing measures to reduce the pressure on the national grid. For instance, the government of South Africa,

* Corresponding author. Tel.: +27 12 420 6767; fax: +27 12 362 5000.
*E-mail address:* murimev@gmail.com.


Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.607

through various agencies, has implemented energy efficiency and conservation strategies to curb wastage, reduce the pressure on the national grid and greenhouse gas emissions [2].

Efficient domestic water heating technologies such as heat pump water heaters (HPWHs) should be adopted. HPWHs operate on the principle of the refrigerant cycle converting one unit of electrical energy to produce three units of thermal energy [6]. This means that they can reduce the energy consumption by two-thirds when they simply replace resistance heaters translating to a reduced cost of energy to the end-users as well as monthly peak demand charges [7]. However, there still exists technological challenges of optimal operation, system designing, sizing and integration of HPWHs. Integration of HPWHs with distributed renewable energy systems would further increase the savings to the owners [8]. Various studies have looked at ways of optimally controlling HPWHs at domestic level incorporating renewable energy systems [8–10]. The studies show that optimal control of HPWHs while incorporating renewable energy systems is an economically feasible solution to providing hot water.

One major drawback with HPWHs, despite their high coefficient of performance, is their slow rate of heating; such that, in situations with sudden demand for hot water, they are unable to meet it. Further, since HPWHs are normally centrally located, there are energy and water losses associated with the hot water conveyance to the consumption point [11]. This paper introduces an optimal control strategy to provide hot water using HPWHs and instant heaters. The HPWH seeks to meet the hot water demand in the kitchen faucet and bathroom sink that require less hot water while the instant heater takes up hot water from the HPWH and only heats it further if it is not at the required temperature. These two water heating devices are powered using both solar energy as well as grid. The optimal controller will minimize the grid energy consumption as well as the operation of the instant heater, essentially saving energy. Further, the grid can accept excess power from the renewable sources through an appropriate feed-in-tariff.

## 2. Controller design

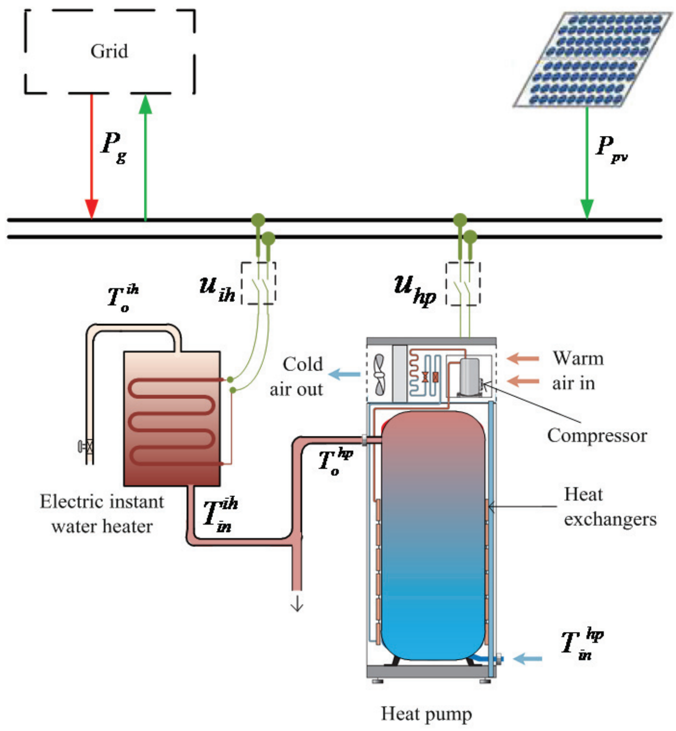


Fig 1: Schematic diagram of the integrated water heating system.