Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 61 (2014) 1511 – 1514

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Optimal scheduling strategy for a grid-connected photovoltaic system for heat pump water heaters

S. Sichilalu*, X. Xia, J. Zhang

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

Abstract

The aim of this paper is to develop an optimal scheduling strategy model for a grid-connected photovoltaic (PV) system to power heat pump water heaters (HPWH). The system is composed of PV modules which are grid-tied. The PV is capable of supplying power simultaneously to the HPWH and domestic loads whilst the grid is a complimentary source. The cost function of this model is to minimize energy cost, while the PV power outputs to the HPWH and domestic appliances are to be maximized. The time-of-use (TOU) electricity tariff is taken into account in the optimal scheduling model. The control variables are the power flows within the branches of the system. The optimal control strategy of this grid-connected PV system can be implemented to reduce the power demand and serve as means of load shifting while meeting technical and operational constraints. This model is shown to have more economical benefits than the solar thermal heaters, because of the possibility of turning house buildings into energy positive if the feed-in tariffs become attractive. A case study was done based on 3x16kW HPWH installed at Pretoria hotel in South Africa. Simulations run over year on selected seasonal dates using actual fluctuating coefficient of performance (COP) of the HPWH. The optimal results show how solar output variation and TOU affect the scheduling strategy of the HPWH. The energy cost savings are as well presented in this paper.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: Heat pump water heater; Optimal scheduling; Photovoltaic; Energy positive buildings; Time-of-use tariff

* Corresponding author. Tel.: +27 12 420 6767; fax: +27 12 362 5000.
E-mail address: sichgroup@yahoo.com; Sam.Sichilalu@up.ac.za.

Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.12.158

1. Introduction

The HPWHs have gained wide applications[1] in offering economical means of heat recovery from the environment for usages in industrial and domestic applications. Most predominant usage of the HPWH is for hot water and space heating[2]. Heat pumps have low energy consumption of about two third [3] less when compared to resistive element water heaters due to its COP. The integration of the distributed renewable energy sources into homes provides huge potential to power loads of lower demand like heat pumps. The hybrid PV system powering heat pumps is an effective tool [4] for demand side management (DSM). Several hybrid systems to power small communities and domestic loads are presented in [5]. However, there is little research in grid-tied PV system to power the heat pumps, making them uneconomical [3] in most developing countries. The optimized models of PV/PV-thermal collector hybrid systems were developed in [6]. In [4]attempts on ideal model for optimal control of a hybrid PV system to power HPWH for DSM are presented. However, our paper provides a first attempt for a greener, practical and economically attractive optimal control model for a grid-connected PV system which considers the TOU tariff. The scheduling strategy of our model can be adopted by home owners intending to turn their dwelling into energy positive buildings.

This paper is structured as follows: Section 2 is the mathematical model while Section 3 is composed of simulation results and conclusion.

Nomenclature

P_i	Control variables which are the power flow in *i-th* branch of the PV-Grid system
$C_{B\,j}$	Electricity buying price [R/kWh] based on TOU tariff.
$P_{hp,j}$	Power consumption of the heat pump during hour *t*

2. Optimization model formulation

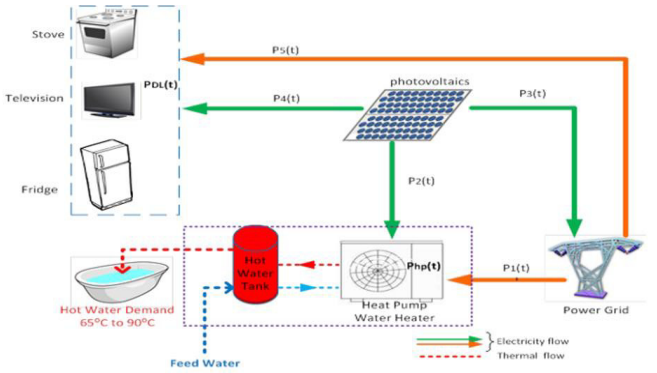

Fig.1. Electrical power and thermal flows

2.1 Objective function

The objective function is expressed in a discrete-time domain encompassing minimal energy costs J_E .