Energy, economic and environmental performance simulation of a hybrid renewable microgeneration system with neural network predictive control

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Abstract The use of artificial neural networks (ANNs) in various applications has grown significantly over the years. This paper compares an ANN based approach with a conventional on-off control applied to the operation of a ground source heat pump/photovoltaic thermal system serving a single house located in Ottawa (Canada) for heating and cooling purposes. The hybrid renewable microgeneration system was investigated using the dynamic simulation software TRNSYS. A controller for predicting the future room temperature was developed in the MATLAB environment and six ANN control logics were analyzed.

The comparison was performed in terms of ability to maintain the desired indoor comfort levels, primary energy consumption, operating costs and carbon dioxide equivalent emissions during a week of the heating period and a week of the cooling period. The results showed that the ANN approach is potentially able to alleviate the intensity of thermal discomfort associated with overheating/overcooling phenomena, but it could cause an increase in unmet comfort hours. The analysis also highlighted that the ANNs based strategies could reduce the primary energy consumption (up to around 36%), the operating costs (up to around 81%) as well as the carbon dioxide equivalent emissions (up to around 36%).

1. Introduction

The depletion of resources as well as an environmental conscience regarding global warming have urged the need for a complete change in energy production, supply and consumption patterns in order to reduce the energy demand as well as to improve the efficiency of energy production systems...
mainly in the residential sector (it has been estimated that buildings consume 40% of the world’s energy and generate 33% of the carbon dioxide emissions [1]).

Micro-cogeneration (MCHP) systems able to produce both heat and power at the point of use (with an electric output lower than 50 kW el according to [2]) are emerging as a suitable approach to reduce energy consumption and pollutant emissions by offering high efficiency and good environmental foot-print, offsetting the need for centrally-generated grid electricity, enhancing energy security and avoiding transmission/distribution losses [3–6]. Today there are several technologies that are capable of providing cogeneration services [7,8] and in the recent years numerous studies have been performed on development, design guidelines, experimental testing, energy, cost and emission analyses, and optimization of MCHP systems [9,10]. Among them, the solar energy conversion into electricity and heat in a single device called photovoltaic thermal (PVT) collector is gaining an increasing attention [11–13]. This is due to the fact that the dual functions of the PVT system result in a higher overall solar conversion rate than that of solely photovoltaic or solar collectors, and thus enable a more effective use of solar energy. In addition to the micro-cogeneration technologies, several studies have recognized that the ground source heat pump (GSHP) is an efficient and environment-friendly option for space heating/cooling of buildings [14–17] and a large number of GSHPs have been used in residential and commercial buildings throughout the world [17] mainly thanks to the advantage of using the ground or groundwater as the heat source-sink with respect to other thermal sources such as the outside air. There are several types of ground loop systems used in GSHPs, but ground-coupled heat pump systems with vertical boreholes are considered as the most suitable option for dwellings (where limited space is available) [16,17]. Combination of MCHP devices to various thermally fed or electrically-driven cooling units (such as GSHP systems) allows to set up a so-called micro combined cooling heat and power (MCCHP) system [18,19], that represents the production in situ of a threefold

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