A novel polygeneration system integrating photovoltaic/thermal collectors, solar assisted heat pump, adsorption chiller and electrical energy storage: Dynamic and energy-economic analysis

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A B S T R A C T

In this paper a dynamic simulation model and a thermo-economic analysis of a novel polygeneration system are presented. The system includes photovoltaic/thermal collectors coupled with a solar-assisted heat pump, an adsorption chiller and an electrical energy storage. The modelled plant supplies electrical energy, space heating and cooling and domestic hot water. The produced solar thermal energy is used during the winter to supply the heat pump evaporator, providing the required space heating. In summer, solar thermal energy is used to drive an adsorption chiller providing the required space cooling. All year long, solar thermal energy in excess, with respect to the space heating and cooling demand, is used to produce domestic hot water. The produced electrical energy is self-consumed by both user and system auxiliary equipment and/or supplied to the grid.

The system model includes a detailed electrical energy model for user storage and exchange with the grid along with a detailed building model. This study is a continuation of previous works recently presented by the authors. In particular, the present paper focuses on the real electrical demands of several types of users and on the analysis of the comfort of building users. Differently from the works previously published by the authors, the present work bases the calculations on measured electrical demands of real users (fitness center and offices). The system performance is analyzed with two different electricity supply contracts: net metering and simplified purchase/resale arrangement. Daily, weekly and yearly results are presented. Finally, a sensitivity analysis is performed in order to determine the system performance as a function of the system main design/control parameters and to evaluate the minimum Simple Pay-Back period. The results outlined a share of the electrical energy storage system on the self-consumed electrical energy of about 20%. The economic profitability is better in case of net metering contract compared to the simplified purchase/resale arrangement one. Moreover, a Simple Pay-Back of about 15 years is achieved for the best configuration, decreasing to 5.6 years in case of capital investment incentive of 65%. The best system configuration, in terms of solar field area, for the fitness center user ranges from 250 to 300 m².

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1. Introduction

This paper deals with the coupled use of solar heating/cooling and electrical energy storage technologies, presenting a transient simulation of a novel polygenerative system. The modelled system is dynamically simulated and an energy-economic analysis is performed. The technologies included in the proposed system are: PhotoVoltaic/Thermal (PVT) collectors, solar assisted heat pump, adsorption chiller and electrical energy storage technologies. The model is developed by the commercial tool Transient System Simulation (TRNSYS) [1], considering both physical components (pumps, solar collectors, valves, etc.) and controlling devices (sensors, controllers, schedules, etc.). Moreover, the simulation tool also includes a number of additional components required to run the simulations and to process the results, such as: calculators, weather data readers, integrators, and plotters. The proposed system is a development of a previous layout, recently presented by the authors [2]. In fact, the layout investigated in this paper includes several major improvements with respect to the
previously investigated system, mainly due to the utilization of an electrical storage system. Moreover, differently from Ref. [2], the present work bases the calculations on the measured electrical demands of real users, namely: a fitness center and offices. In addition, the present paper also includes a detailed evaluation of buildings occupants comfort, performed by a detailed methodology for the assessments of dynamic thermal loads of buildings. Finally, this work also introduces a novel comprehensive model, developed in order to manage the electric flows of the system. In particular, in such model two different modes for the electrical energy exchange with the grid are taken into account: net metering and simplified purchase/resale arrangement contracts. The system energy and...
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