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Economic dispatch of a bioclimatic office building considering thermal energy, electricity and water demands

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Abstract. Energy and other resources management in production systems is a common topic in recent literature as many environmental and economic issues are related to the efficient use of their devices. In this sense, conversion and storage models based on input-output balances are helpful to determine the combination of resources that allow to operate a plant with the lowest possible cost. This paper is aimed at analyzing the optimal flows of resources that would meet the demands of a bioclimatic building, taking into account the characteristics of its facilities, which includes both photovoltaic modules and solar collectors to produce self-consumption electric and thermal energy. The simulation results for two different days of 2018 have been included. They verify the validity of the proposed model, which could be extended for carrying out analyses on similar buildings, modelled as an energy hub, in order to assess its optimality and proposing management policies.

Key words. Energy hubs, multi-energy systems, self-consumption, solar modules, optimization.

1. Introduction

Energy consumption in residential and commercial buildings represents over the 40% of the total energy consumption in developed countries and near the same amount of CO_2 emissions [1], [2], which are the main responsible for the greenhouse effects and global warming. Renewable energies can reduce the global CO_2 emissions and, at the same time, allow the governments to fulfill their global agreements about climate change, providing clean, cheap and durable energy sources. However, because of the intermittent and stochastic nature of those related to weather conditions, they cannot be used to produce power uninterruptedly and often require storage systems and combining multiple energy vectors to implement flexible and efficient management strategies.

An energy hub (EH) is considered as a unit where the production, conversion, storage and consumption of different energy carriers takes place, representing an interface between different energy infrastructures and/or loads [3]. Some authors consider it a promising option for energy management of Multi-Energy Systems (MES) [4], and its ins and outs have been scrutinized in several reviews on the concept itself [5], optimal management [6], uncertainty [7] or comprehensive approaches [8]. Particularly, it is possible to find several works in literature that address the management of MES in buildings using the EH concept, either with just control purposes (meeting the heating, cooling and electricity demands) [9], [10] or to design a new facility [11], [12].

In this work, the economic dispatch of a real bioclimatic building is presented where not only energy (thermal energy and electricity) is modelled and managed but also water demand, which produces a shiftable load in form of electricity. This task is done by exploiting the EH concept and formulating a linear input-output model for conversion and storage processes. The real building is the CIESOL research center [13], a bioclimatic building which can be considered a MES since it has both conventional energy sources and renewable ones.

The rest of the paper is organized as follows: Section 2 is devoted to present and describe the CIESOL building and its equipment, whereas Section 3 presents the model proposed for the CIESOL building. The main results from this work are presented and discussed in Section 4 and the conclusions deduced from them are summarized in Section 5.

2. Scope of the work

The work presented in this paper has selected the CIESOL research center (http://www.ciesol.es) as a reference building, see Fig. 1. It is placed inside the Campus of the University of Almería (South-East of Spain) under typical desert Mediterranean climatic conditions. This building occupies a surface of 1072 m^2 divided into two floors and, as it was built following bioclimatic criteria, it has several passive and active approaches.

The most representative passive strategies adopted at CIESOL building are the setback of windows which faces South and East, the use of different types of enclosures as a function of the orientation and the shadowing of the rooftop through the installation of both a photovoltaic field and a solar collector field.

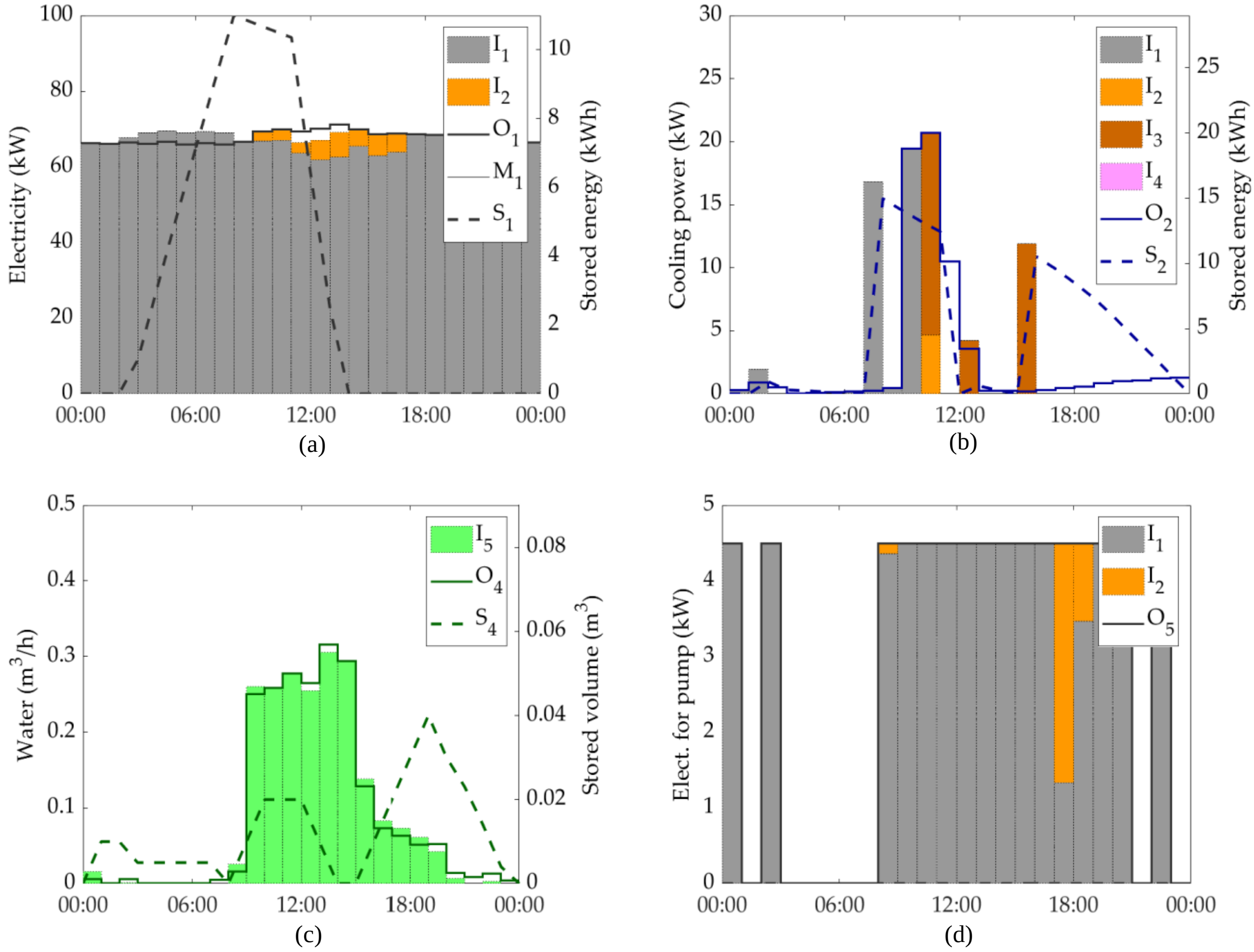

Fig. 4. Optimal economic dispatch of the resources (Coordinated Universal Time +2, September 29th, 2018)

Note that both water (Figs. 4(c) and 5(c)) and thermal (Figs. 4(b) and 5(b)) demands are concentrated during the mid-hours of the day due to working schedules, but electricity (Figs. 4(a) and 5(a)) demand remain nearly immutable during the whole period because of the equipment that operate in the building constantly. Thermal and electric demands are met, when possible, by means of solar resources since they are freely available in contrast to purchasing propane and/or electricity. However, the size of the photovoltaic field is not enough to provide the required amount of power by the building, so it is self-consumed instead of sold and most of the energy needed is acquired via the public utility grid. Also, there exists correspondence between Figs. 4(c) and 4(d) and Figs. 5(c) and 5(d) as the impulsion pump is activated at any time water is provided from the public grid. Because the water storage system flow is physically limited, the amount of water charged during a sample periods tends to be as high as possible: in order to take advantage of the electricity that would be spend anyway to feed the pump.

The storage system management is closely related to both the price of the resources and the equipment characteristics. See, for example, Figs. 4(a) and 5(a), where owing to the lower price before 8 a.m. the batteries are filled early in the morning and discharged after. In the case of water (Figs. 4(c) and 5(c)), because the irrigation pump will be needed during the mid-period of the day, it is preferable not to use it even if the electricity price is low unless there is some water demand (as at 00:00 both days) .

5. Conclusion

Considering the optimization-based framework presented in this work, the basis for carrying out further analyses on similar buildings, modelled as an energy hub and validated in a case study, have been set up. These could include assessing necessities such as increasing the storage systems' capacity or adding different conversion technologies. Both constitute design problems that can be solved employing a multi-level approach [12] in which a genetic algorithm generates different structures of energy hub based on the presented model. In that sense, addign new components is not an issue since the formulation does not need to be subtantially modified because of the use of matricial notation.

Besides, the problem could be integrated into a receding horizon strategy aimed at managing shiftable loads while updating the predictions (weather, electricity price…). That would constitute a control approach in which uncertainty is taken into account and could involve using the dispatch results as inputs for lower-level control loops.

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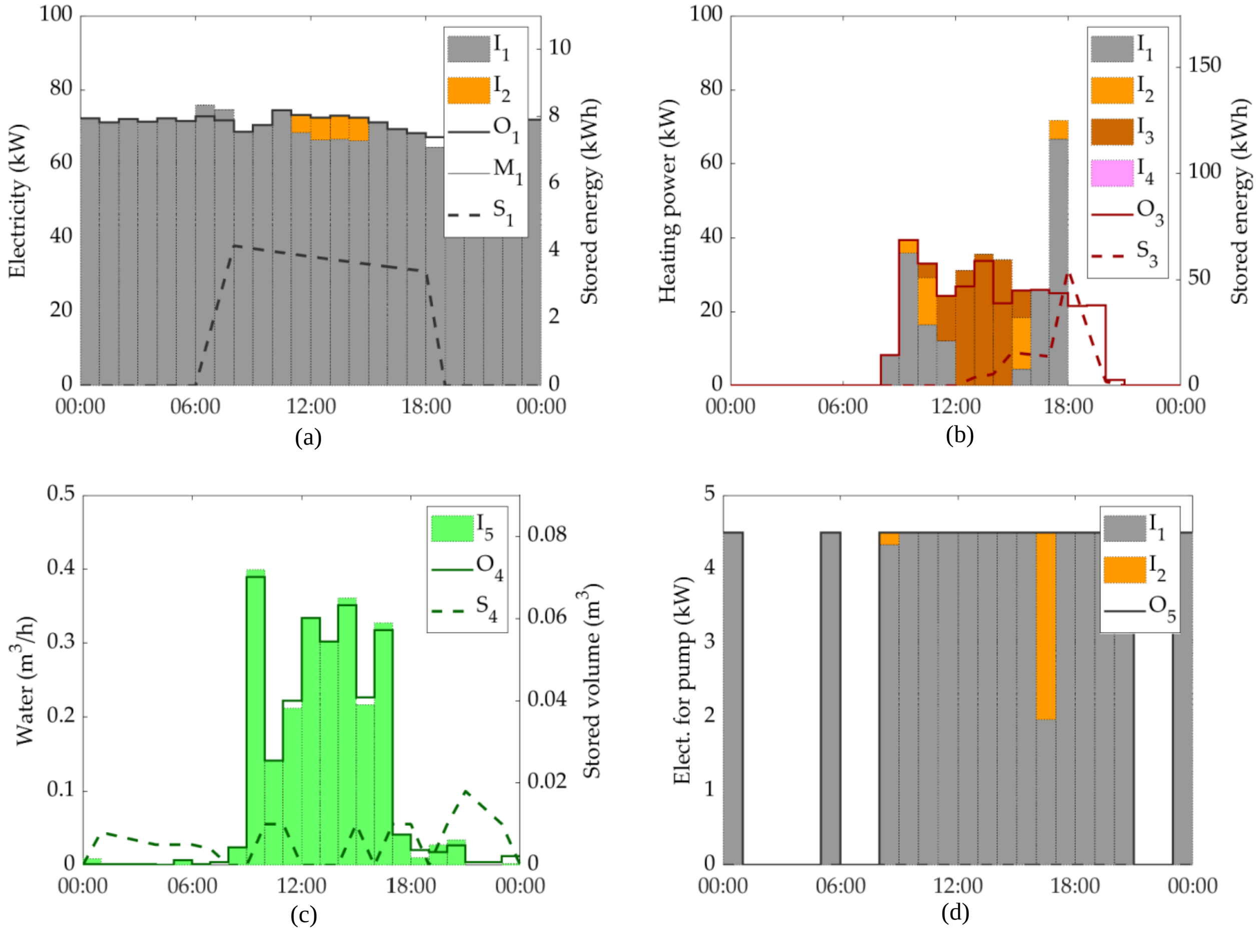

Fig. 5. Optimal economic dispatch of the resources (Coordinated Universal Time +1, February 3rd, 2018)

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