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Optimization of load allocation strategy of a multi-source energy system by means of dynamic programming

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Abstract

Multi-source systems for the fulfillment of electric, thermal and cooling demand of a building can be based on different technologies (e.g. solar photovoltaic, solar heating, cogeneration, heat pump, absorption chiller) which use renewable, partially renewable and fossil energy sources. The main issues of these kinds of multi-source systems are (i) the allocation strategy which allows the division of the energy demands among the various technologies and (ii) the proper sizing of each technology.
Furthermore, these two issues proves to be deeply interrelated because, while a wiser energy demand allocation strategy can lead to significant reductions in primary energy consumption, the definition itself of an optimal allocation strategy strongly depends on the actual sizing of the employed technologies. Thus the problem of optimizing the sizing of each technology cannot be separated from the definition of an optimal control strategy. For this purpose a model of a multi-source energy system, previously developed and implemented in the Matlab® environment, has been considered. The model takes account of the load profiles for electricity, heating and cooling for a whole year and the performance of the energy systems are modelled through a systemic approach. A dynamic programming algorithm is therefore employed in order to obtain an optimal control strategy for the energy demand allocation during the winter period. While the resulting control strategy is non-causal and therefore not suitable for the implementation on a real-time application, it allows the definition of a benchmark on the maximum primary energy savings achievable with a specific sizing solution. This result is therefore very helpful both in comparing different solutions and in subsequently define a proper causal control strategy. Finally, the model is applied to the case of a thirteen-floors tower composed of a two-floor shopping mall at ground level and eleven floors used as offices.

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Nomenclature

A	gross area
AB	auxiliary boiler
ASHP	air source heat pump
c	coefficient
CHP	combined heat power
COP	coefficient of Performance
DP	dynamic programming
E	energy
f	energy conversion factor
GSHP	ground source heat pump
k	time variable
load	ratio between actual power and nominal power
P	power
PE	primary energy consumption
PV	photovoltaic
STH	solar heating
STORAGE	storage
t	time
u	input
x	state
XSHP	generic source heat pump
y	output
η	efficiency
π	control policy

Subscripts

available	available space in the storage
demand	demand
diss	dissipation
el	electric
fuel	fuel
in	entering
max	maximum
min	minimum
nom	nominal
out	outgoing
request	to be fulfilled
sent	sent to the grid
startup	start up
taken	taken from the grid
th	thermal
unused	not used for demand fulfilment