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Editorial: Optimization of energy autonomy in buildings with renewable energy sources and battery storage

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Editorial on the Research Topic
Optimization of energy autonomy in buildings with renewable energy sources and battery storage

The theme of this Frontiers in Energy Research Special Issue (SI) was based on the topic editors' expertise and previous work (see, for example,Georgiou et al., 2019; Gržanić et al., 2022), and attempted to bring together miscellaneous work addressing keywords such as Building Energy Optimization, nearly Zero Energy Buildings, Electrical Energy Storage, Linear Programming, Artificial Neural Networks, Genetic Algorithm, Convex optimization, Photovoltaics, Demand Side Management, Building Management Systems.

All new buildings are currently being built in a way that minimizes primary energy consumption (energy from utility networks) while increasing their percentage of renewable energy sources (RES). The levelized cost of electricity has been rapidly decreasing due to newer, more efficient and cheaper technologies, which to some extent can compete with conventional generation units. Hence, the usage of electrical storage has raised a great interest of both academics and professionals. Furthermore, studies have shown that buildings with electrical storage can reduce electricity bills while increasing self-consumption of onsite Renewable Energy Generation (REG).

The SI can serve as a guide to specific problems of Building Energy Management, by presentation of ideas, methods and results related to energy optimization. This could include studies related to convex mathematical optimization or any other technique for reducing energy consumption in buildings, such as in real-time and through storage, with or without integrated RES. Techniques such as Genetic Algorithms, Artificial Neural Networks, Machine Learning can be integrated to this end.

The SI points to the development of new mathematical methods and computational algorithms, as well as the application of new or existing methods to problem solving in this research area.

These include experimental studies in combination with numerical/computational work, where assessing the accuracy of computational solutions through verification and validation is essential. Themes relevant to this SI include: Optimization of the integration of

RES in buildings; optimized dispatch of battery energy for managing energy consumption profiles within buildings; achieving energy targets of nearly Zero Energy Buildings (nZEBs), using RES and battery, in real-time, once the building is inhabited and used; Demand Side Management (DSM) and Demand Response (DR) for managing the nZEBs' energy, in real-time, once the building is inhabited and used.

The outcome of this SI was a selection of 4 articles by 14 authors from 5 countries as follows.

(i) Twum-Duah et al. performed a comparison of direct and indirect flexibilities in relation to self-consumption of an office building. The purpose of this paper is to provide a method for assessing the impact of direct and indirect flexibilities on the self-consumption of office buildings. The goal is to assess how both the human actors and technical interventions can affect or mitigate deviations in the self-consumption level of a building from its optimal. This paper considers the Predis-MHi platform (a living lab) as a representative case study and applies a Mixed Integer Linear Programming optimization to manage both the direct (stationary battery charging) and indirect flexibilities (Electric Vehicle charging when users plug and unplug their vehicles). Our results indicate that the potential for a building's self-consumption improvement using indirect flexibilities does exist and can be quantified. However, this type of flexibility is highly dependent on human actors which presents a high level of uncertainty and is difficult to account for in all stages of a building's development and use. Direct flexibilities such as stationary battery storage can be used to mitigate the undesired effects of having significant levels of indirect flexibilities on a tertiary sector building's energy performance. The results from this study could potentially be modeled into an indicator, which would serve to influence occupant behavior towards a desired optimal.

(ii) Rastegarpour and Ferrarini addressed energy management in buildings in relation to modeling and control design. This paper presents a comparative analysis of different modeling and control techniques that can be used to tackle the energy efficiency and management problems in buildings. Multiple resources are considered, from generation to storage, distribution and delivery. In particular, it is shown what are the real needs and advantages of adopting different techniques, based on different applications, type of buildings, boundary conditions. This contribution is based widely on the experience performed by the authors in the recent years in dealing with existing residential, commercial and tertiary filed buildings, with application ranging from local temperature control up to smart grids where buildings are seen as an active node of the grid thanks to their ability to shape the thermal and electrical profile in real time. As for control models, a wide range of modeling techniques are here investigated and compared, from linear time-invariant models, to time-varying, to nonlinear ones. Similarly, control techniques include adaptive ones and real-time predictive ones.

(iii) Jasim et al. presented a grid-connected microgrid energy management system of optimal sizing through an optimization algorithm. Renewable energy systems, particularly in countries with limited fossil fuel resources, are promising and environmentally sustainable sources of electricity generation. Wind, solar Photovoltaic (PV), and biomass gasifier-based systems have gotten much attention recently for providing electricity to energy-deficient areas. However, due to the intermittent nature of renewable energy, a completely renewable system is unreliable and may cause operation problems. Energy storage systems and volatile generation sources are the best way to combat the problem. This paper proposes a hybrid grid-connected wind-solar PV generation Microgrid (MG) with biomass and energy storage devices to meet the entire value of load demand for the adopted buildings in an intended region and ensure economic dispatch as well as make a trade in the electricity field by supplying/receiving energy to/from the utility grid. The control operation plan uses battery storage units to compensate energy gap if the priority resources (wind turbine and solar PV) are incapable of meeting demand. Additionally, the biomass gasifier is used as a fallback option if the batteries fail to perform their duty. At any time, any excess of energy can be utilized to charge the batteries and sell the rest to the utility. Additionally, if the adopted resources are insufficient to meet the demand, the required energy is acquired from the utility. A Hybrid Grey Wolf with Cuckoo Search Optimization (GWCSO) algorithm is adopted for achieving optimal sizing of the proposed grid-connected MG. To assess the proposed technique's robustness, the results are compared to those obtained using the Grey Wolf Optimization (GWO) algorithm. The GWCSO method yielded a lower total number of component units, annual cost, total Net Present Cost (NPC), and Levelized Cost Of Energy (LCOE) than the GWO algorithm, whereas the GWCSO algorithm has the lowest deviation, indicating that it is more accurate and robust than the GWO algorithm.

(iv) Zhao et al. proposed a CSP-PV-wind hybrid power generation system and its optimal scheduling with regard to demand response. In order to solve the problem of there being a high proportion of wind and photovoltaic (PV) abandonment in the new energy system, an optimal dispatching method of concentrated solar power (CSP)–PV–wind hybrid power generation considering demand response is proposed. First, on the basis of the combination of wind and PV power stations and CSP stations, electric heating (EH) devices are used to convert unconsumed wind and PV power into thermal energy stored in the thermal storage system of the CSP station. Second, based on the difference in response time and response volume of customers, a stepped incentive-based demand response (IBDR) approach is introduced. Thus, a CSP–PV–wind power optimal dispatch model taking into account IBDR is established to achieve coordinated source-load dispatch. Finally, the CPLEX solver is invoked to optimize day-ahead scheduling with the goal of the lowest system comprehensive cost. Example analysis is used to confirm the proposed method's usefulness in enhancing the system's wind and PV power consumption capacity and reducing the system's comprehensive cost.

Author contributions

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