Energy management 310 kWh

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Modern power systems are changing. They now use more renewable energy sources (RESs), such as solar and wind power, as well as dynamic loads and batteries. This shift is turning traditional power systems into smart microgrids (MGs). These new systems offer technical and economic benefits, like reliability, cost-effectiveness, and reducing greenhouse gases. But to make sure everything runs smoothly, we need to monitor and control these complex systems (Ullah et al. 2023).

Energy management controllers (EMCs) have become increasingly important in recent years. With a focus on sustainable development and efficient energy use, research in this area has advanced alongside technological improvements. These controllers are all about optimizing energy consumption, improving efficiency, and integrating RES into the power grid. They are crucial for managing smart grids and MGs efficiently (Chen 2018).

Early EMSs focused on direct load control (DLC) architectures, which helped manage energy demand in residential areas with multiple buildings (Singh et al. 2023). More recently, stochastic optimization frameworks have been introduced. These frameworks use mathematics to minimize costs and optimize MG operation, taking into account factors such as seasonal load patterns and RES (Dagdougui et al. 2020).

To manage energy effectively, energy management (EM) programs are essential. They help monitor and control energy consumption patterns, minimizing waste and focusing on efficiency. Demand-side management (DSM) plays a crucial role in smart grids, allowing consumers to adjust their energy use based on incentives and electricity prices (Bakare et al. 2023). DSM techniques include peak clipping, load shifting, and demand response programs, all aimed at improving the sustainability and reliability of power grids (Hussain et al. 2018).

The evolution of energy management system (EMSs) has been influenced by advancements in hardware and software architectures, leading to standardized industry standards and sophisticated functionality. The field has evolved to improve energy efficiency, reduce costs, and address environmental concerns. Research on EMCs has evolved to address efficient energy utilization, renewable energy (RE) integration, and system optimization. Ongoing technological and research advancements continue to shape the field and drive innovation in EM practices.

A detailed comparison and summation of recent control methods for MG systems, including hierarchical control structures, with the goal of achieving sustainable energy supply.

A review of various EMCs, including classical, heuristic, and intelligent algorithms, along with an analysis of their applications and real-life implementations.

Figure 1 outlines three main control strategies: hierarchical, decentralized, and centralized, each with its own advantages and challenges in managing MG systems.