Energy & Buildings 350 (2026) 116616

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enbuild

Load balancing algorithm for smart building based on DC bus

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ARTICLE INFO

Keywords:
DC building
Dual DC bus
USB type-C
IEC 61850
Dynamic topology reconfiguration

ABSTRACT

According to environmental concerns and increasing demand for electricity, there has been significant progress in distributed power generation, and DC buildings have been studied for improving the use of systems. This study introduces a new architecture that departs from the traditional single-bus power grid configuration. The connection of the bus and loads can be controlled using a load balancing algorithm, which is a method of controlling the building bus. It is also designed to transmit power from the energy router to the DC bus and from the DC bus to the loads via USB Type-C. In addition, DC smart buildings do not operate independently, in some cases they need to be connected to other systems. Therefore, interoperability between heterogeneous devices must be ensured. the proposed architecture is designed as a IEC 61850 based communication network and data model, including a method for modeling DC buildings using Logical Node and a communication architecture to obtain data in real-time. A testbed was built for the main aspects of the building proposed to confirm the feasibility of the architecture in terms of power and communication aspects. It is expected that the architecture can be used in combination with various future grid control technologies and can be used for various study utilizing dual DC bus structure and USB Type-C based power delivery.

1. Introduction

Along with the method of obtaining and using electricity from renewable energy resources instead of fossil fuels to achieve carbon neutrality, interest is growing in DC-based grids that attempt to replace AC grids, which are difficult to connect to various forms of power sources [1–3]. Unlike AC grids, where loads cannot directly connect to solar power or an ESS (Energy Storage System) and require power conversion devices such as inverters and converters to consume electricity in AC form, DC grids have fewer power conversion stages and offer flexibility in interfacing with RES (Renewable Energy Source) [4–6]. Furthermore, the prevalence of DC-powered devices is steadily increasing, and most electrical end-use equipment in buildings can operate directly on DC power [7]. Against this backdrop, research on DC buildings that operate self-generation sources like RES and ESS is being conducted to address the inefficiencies of AC buildings [8]. However, due to the inherent characteristics of RES, the amount of power generated fluctuates depending on environmental conditions, leading to continuous changes in generation capacity. In DC buildings, both generation and consumption are inherently variable. As a result, it is essential for DC buildings to collect various measurements related to supply and consumption and to issue appropriate operational commands through control algorithms or systems.

Research on load scheduling in smart buildings and nano/microgrids has been conducted to develop effective control systems. References [9–11] address islanding operation strategies to secure self-sufficiency in preparation for utility outages or planned power interruptions. However, these studies assume a single DC bus, making them vulnerable when the bus itself fails inside the building or when power converters connected to DERs (Distributed Energy Resources) fail. Meanwhile, an approach that minimizes electricity costs by utilizing on-site generation in accordance with price signals and restricting grid interconnection [12,13], as well as an approach that balances supply and demand by controlling the charge/discharge timing of an ESS and connecting loads in response to intermittent generation [14], has also been proposed. Yet these studies likewise focus on cost minimization while assuming that all loads are supplied from a single DC bus; therefore, building operation methods centered on load balancing to prevent grid overloads and bottlenecks are additionally required. In a direction that complements the limitations of the single-bus assumption, a dual-bus building architecture has been proposed to replace or augment a single bus [15,16]. Reference [15] presents a switching strategy that selects the bus with the higher voltage while imposing hysteresis and a minimum dwell time to suppress chattering. However, without explicit constraints on the inter-bus voltage difference during switching, large voltage disparities can cause inrush and transient voltage deviations. Reference [16] performs

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https://doi.org/10.1016/j.enbuild.2025.116616
Received 20 July 2025; Received in revised form 4 October 2025; Accepted 18 October 2025
Available online 30 October 2025
0378-7788/