Control of PV/Battery/PEM fuel Cell DC Microgrid Through Model Predictive Control Design

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Abstract:

Model Predictive Control (MPC) is emerging as a highly effective method for managing DC micro grids, offering a smarter, more adaptive approach to handling voltage fluctuations, power flow, and energy efficiency compared to traditional control techniques. As DC micro grids continue to incorporate a mix of renewable energy sources—such as solar panels, batteries, and fuel cells—they face growing challenges tied to power inconsistencies, voltage instability, and operational inefficiencies, all of which can drive up costs. This study introduces a Decentralized Distributed Model Predictive Control (DDMPC) framework specifically designed to address these issues. Building on prior studies that applied centralized MPC to micro grids, this study extends the method via decentralization of controllers, this approach assigns a local DDMPC controller to each energy subsystem—namely the PV array, the battery storage unit, and the PEM fuel cell. Each controller operates independently using real-time, localized data, making decisions that contribute to the overall balance, stability, and efficiency of the micro grid.

The control goals—such as maintaining a stable DC bus voltage, minimizing switching losses, and ensuring economic energy usage—are all embedded within a tailored cost function. These cost functions help determine the best switching decisions at each moment, allowing the system to adapt proactively to changing conditions. To deal with the complex and non-convex nature of the control problem—mainly due to the discrete switching states of power converters—a Mixed-Integer Nonlinear Programming (MINLP) algorithm is used. This allows each local controller to find the optimal solution within its limited decision space, while still contributing to the larger system goals. Simulation results, carried out in MATLAB/Simulink under varying sunlight and load scenarios, show that the proposed DDMPC approach delivers reliable performance. It ensures voltage stability, enhances energy coordination, and supports efficient, real-time decision-making across all parts of the micro grid.

Keywords:

DDMPC, Model Predicitve control, Energy Management, MINLP, DC microgrid.