Title

Nonlinear Control and ANN for Renewable Hybrid Energy Applications in AC/DC Micro Grid

Abstract:

The massive dependence on renewable energy sources in the modern power systems has heightened the need to develop control and energy management strategies that are more complex and dynamic and which can guarantee stability, strength, and high dynamic behavior in the hybrid AC/DC microgrids. Photovoltaic generation, hybrid energy storage, power electronic converters and electric vehicle charging structures are nonlinear, strongly coupled and highly uncertain due to intermittent generation, load variations and parameter mismatches. In this situation, the traditional linear and rule-based control methods tend to be ineffective in ensuring resilient and stable system behavior.

This thesis formulates and experimentally proves a unified energy-systems framework founded on nonlinear robust control and artificial neural network (ANN) algorithms to renewable hybrid energy uses of AC/DC microgrids. Sophisticated nonlinear control strategies, such as adaptive barrier-based super-twisting sliding mode controllers and synergetic super-twisting control systems are formulated rigorously in power electronic converters, interfaces among hybrid energy storage and electric vehicle charging systems. Lyapunov stability analysis is used to prove global asymptotic and finite time convergence, and the ability to remain robust to matched and unmatched disturbance, parameter variation and to external perturbation. The proposed controllers have much higher chattering reduction, transient-performance, and steady-state-accuracy improvement over traditional sliding mode and linear control systems.

To further ensure system intelligence and flexibility, ANN-based methods, in which ANFIS and variants of recurrent neural networks, such as those based on LSTM, are also introduced to optimize photovoltaic maximum power point in a rapidly switching environmental factors such variations of irradiance and temperature. Moreover, the strategies of intelligent energy management approach is formulated based on fuzzy rule based control and optimized by deep reinforcement learning. The deep deterministic policy gradient-based energy management framework is developed to optimize dynamical power distribution between renewable sources, hybrid energy storage systems, and electric vehicle charging points with a direct consideration of the efficiency, component strain and operational limits.

Charging stations of electric vehicles running on grid-to-vehicle, Vehicle to grid and Vehicle to Vehicle modes are explored as one of the major domains of application of the proposed framework. The proposed control and energy management framework allows the flow of power in both directions, coordinated energy, and grid-support, which allows a natural integration of electric mobility in renewable-based AC/DC microgrids.

Extensive experimental validation is done on the basis of detailed simulations and hardware-in-the-loop experiments, which reveal a significant improvement in voltage regulation, dynamic response, robustness, and energy usage. The findings affirm that the suggested nonlinear and intelligent control framework

offers a viable, scalable and resilient platform of renewable hybrid energy solution in AC/DC microgrids with embedded electric vehicle infrastructures.

Keywords: *Renewable Hybrid Energy Systems, AC/DC Microgrids, Nonlinear Robust Control, Hybrid Energy Storage Systems, Power Electronic Converters, Artificial Neural Networks, ANFIS, LSTM-Based MPPT, Intelligent Energy Management Systems, Fuzzy Control, Deep Reinforcement Learning, Electric Vehicles, Hardware-in-the-Loop Validation*

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