Abstract

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Energy Management and Control for Hybrid Renewable Energy Sources in Rural Area

Recently applied islanded DC micro-grids (MGs) in rural areas do not rely solely on single dominant power source. Various local renewable energy sources (RESs) integrates together forming the DC MG power generation units. RESs are characterized by their dependency on weather and environmental conditions. Hence, their maximum available generated power must be continuously tracked for efficiency improvement purposes. Owing to the intermittent nature of RESs and demand side variation, energy storage systems (ESSs) are mandatory to ensure system reliability and improve power quality. Insufficient/surplus power generation causes the MG DC bus voltage to /rise, yet it can be balanced through discharging/charging of the ESSs. Thus, the MG performance is deeply dependent on the ability of the energy management system (EMS) to perform the maximum power point tracking (MPPT) for local RESs, achieve coordinated control for RESs and ESSs integration and ensure DC bus voltage stabilization. For RESs MPPT control the most practical applied method is the well-known Perturb and Observe (P&O) for its simplicity and low cost implementation. However, conventional P&O algorithm suffers two main drawbacks excessive oscillation around the MPP in steady-state and MPP mismatch under rapidly changing atmospheric conditions. In addition, hybridizing of RESs leads to the existence of continuous and discrete characteristics together in one converting system. This thesis primarily proposes, an improved P&O based State-Flow MPPT algorithm featuring two degree of freedom, in which the event driven system (MPPT) behaviour is modelled by describing it in terms of transitions among states under certain conditions. Secondarily, an extended parallel operating State-Flow based MPPT algorithm is further proposed to be a challenging solution for the independent control of the hybrid system, where continuous control characteristic can present during a certain working state while discrete one is indicated along state transitions. Two possible configurations for the hybrid system are proposed two separate DC/DC converters and dual input single output converter (DISO) configurations. Finally it is proposed, DC system behaviour modelling using State-Flow leading to the whole control strategy design which concern RESs MPPT, RESs and BESS coordination, power system stability and DC bus voltage regulation. Simulation and experimental results validate the effectiveness and applicability of the proposed algorithm, both results show the superiority of the proposed State-Flow based MPPT in reducing the RESs power oscillations at steady-state in various operating conditions in addition to its faster start-up and transition operation without divergence from the MPP during sudden varying weather conditions. Hence, the proposed algorithm can overcome the main drawbacks of the conventional algorithm, in addition to applicability on hybrid RESs regardless of the system structure. The proposed EMS based State-Flow controller presents a generic structure, simplified implementation, seam-less smooth modes' transition and fast dynamic response providing the system power stability required while considering battery limitations.