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Optimal operation of an isolated microgrid with battery storage using semidefinite programming

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The concept of microgrids implies that the power is generated locally regardless of whether it is geographically isolated or islanded. The rise of distributed power has resulted in new challenges, such as voltage fluctuations due to varying solar PV generation. Less sophisticated and fully automated microgrid control mechanisms have been adopted; these rely on simple supply/demand balance settings and the battery state of charge. A more advanced control requires the use of an energy management system that is able to optimally provide reliable electricity power at minimum cost.

Power system operators use optimisation algorithms for the scheduling and dispatch of generators (REF). The most common optimisation model is based on the approximation of optimal power flow (LDC model) providing relatively fast convergence. However, Zhong (2018) states that the solution of the LDC model for transmission networks leads to an error between 3-10% relative to the exact solution provided by an AC optimal power flow (OPF) problem. Given that reactive power and the resistance of distribution lines are neglected in this model, the potential violations of voltage constraints cannot be captured. Thus, the LDC model is not applicable for distribution networks. On the other hand, AC OPF is a non-convex, nonlinear problem, which cannot be solved using today's solvers.

Several convex AC OPF relaxation techniques have shown promising results solvable in polynomial time for distribution networks with radial topology. Among them, semidefinite programming (SDP) has received particular attention since Laveai et al. (2012) formulated conditions when a convex SDP problem guarantees an exact solution (zero duality gap) to the OPF problem. Lesieutre et al. (2012) analysed the limitation of convex SDP. Gan & Low (2014) presented conditions when semidefinite relaxations have a zero duality gap in radial networks. Coffrin et al. (2016) proved that SDP is guaranteed to yield a tighter duality gap than second-order cone programming (SOCP) yet is computationally more expensive. Hijazi et al. (2016) introduced polynomial SDP cuts resulting in better computational efficiency. Venzke et al. (2018) proposed convex SDP for chance-constrained AC OPF considering multiple periods with wind forecast errors.

Following Laveai's and Venzke's work, this study applies convex SDP for the operation of an isolated microgrid with high solar penetration, battery storage and generator. To the authors' knowledge, no paper has attempted to apply SDP for AC OPF for a microgrid with solar PV battery storage yet. The main contributions can be summarized as follows:

- Formulating an SDP problem for microgrids with a battery storage system;
- Presenting the stability of the SDP model at various solar PV penetration levels;
- Providing a comparison of a microgrid control using a simple load balance strategy, LDC model and convex SDP model.

The Monash microgrid with 25 nodes (seven of them with solar PV) and battery storage is used as a case study. To simulate an autonomous microgrid, it is considered that the power is supplied from a diesel generator with a quadratic cost function instead of the grid. The problem is solved using the

MOSEK solver through the MATLAB toolbox YALMIP on a computer with Intel i7-7600U multiple core CPU at 2.9 GHz and 16GB of RAM.

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