Sequential Convex Programming for Power Set-point Optimization in a Wind Farm using Black-box Models, Simple Turbine Interactions, and Integer Variables

We consider the optimization of power set-points to a large number of wind turbines arranged within close vicinity of each other in a wind farm. The goal is to maximize the total electric power extracted from the wind, taking the wake effects that couple the individual turbines in the farm into account. For any mean wind speed, turbulence intensity, and direction we find the optimal static operating points for the wind farm. We propose an iterative optimization scheme to achieve this goal. When the complicated, nonlinear, dynamics of the aerodynamics in the turbines and of the fluid dynamics describing the turbulent wind fields' propagation through the farm are included in a highly detailed black-box model, numerical results for any given values of the parameter sets can easily be evaluated. However, analytic expressions for model representation in the optimization algorithms might be hard to derive and their properties are often not suitable for computationally efficient optimization either. To handle this, we propose a sequential convex optimization method, perturbing the model in each iteration, and demonstrate a typical convergence in fewer than 10 iterations. We derive a coupling matrix from the wind farm model, enabling us to use a very simple linear relationship for describing the turbine interactions. In addition, we allow individual turbines to be turned on or off introducing integer variables into the optimization problem. We solve this within the same framework of iterative convex approximation and compare with mixed-integer optimization tools. We demonstrate the method on a verified model and for various sizes and configurations of the wind farm. For all tested scenarios we observe a distribution of the power set-points which is at least as good as, and in many cases is far superior to, a more naive distribution scheme. We employ a fast convex quadratic programming solver to carry out the iterations in the range of microseconds for even large wind farms.