



An application of model predictive control to the dynamic economic dispatch of power generation

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ABSTRACT

Two formulations exist for the problem of the optimal power dispatch of generators with ramp rate constraints: the optimal control dynamic dispatch (OCDD) formulation based on control system models, and the dynamic economic dispatch (DED) formulation based on optimization. Both are useful for the dispatch problem over a fixed time horizon, and they were treated as equivalent formulations in literature. This paper first shows that the two formulations are in fact different and both formulations suffer from the same technical deficiency of ramp rate violation during the periodic implementation of the optimal solutions. Then a model predictive control (MPC) approach is proposed to overcome such a technical deficiency. Furthermore, it is shown that the MPC solutions, which are based on the OCDD framework, converge to the optimal solution of an extended version of the DED problem and they are robust under certain disturbances and uncertainties. Two standard examples are studied: the first one of a ten-unit system shows the difference between the OCDD and DED, and possible ramp rate violations, and the second one of a six-unit system shows the convergence and robustness of the MPC solutions, and the comparison with OCDD as well.

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1. Introduction

The dynamic dispatch problem of power generation was first considered in the early 1970s in a control system framework in Bechert and Kwatny (1972), motivated by an optimal control formulation and solution done in Kwatny and Bechert (1973). It was argued that a dynamic dispatch solution was more accurate than the static economic dispatching (SED) (Wood & Wollenberg, 1996), in the sense of its look-ahead capability by solving the optimization problem with the predicted load demand over a time horizon consisting of several time intervals and considering the ramp rate constraints. Ramp rate constraint is a dynamic constraint used to maintain the life of the generators (Han & Gooi, 2007; Wang & Shahidepour, 1995; Wood, 1982).

The optimal control dynamic dispatch (OCDD) formulation is to model the power generation by means of state equations where the state variables are the electrical outputs of the generators and the control inputs are the ramp rates of the generators. The OCDD problem was originally described in Bechert and Kwatny (1972) and Kwatny and Bechert (1973). In these papers, the optimal feedback controller was synthesized only for the special case of two generators sharing load owing to

computational problems. Bechert and Chen (1977) proposed a multi-pass dynamic programming approach to solve the OCDD problem and obtained the optimal generator output trajectories for up to five generators. The proposed algorithm finds only a local optimal schedule, and the required computer memory and calculation time increase exponentially with the number of generators. The main drawback of the approaches proposed in Bechert and Kwatny (1972), Kwatny and Bechert (1973) and Bechert and Chen (1977) has been the limitation on the problem dimensions.

Ross and Kim (1980) proposed a successive approximation approach with dynamic programming for solving the OCDD problem without limitation of the number of units. The valve-point effects is considered. The large problem with ramping constraints is broken down into smaller subproblems. Each subproblem pairs one unit with an artificial unit and is solved via dynamic programming by discretizing the generation outputs. The feasibility of the problem has been demonstrated on a problem involving 15 units and 16 intervals. However, execution time and problem size increase almost exponentially with the number of units.

It seems that the OCDD approach has been gradually abandoned for almost 20 years until in 1998 the OCDD problem was revisited again by Travers and Kaye (1998). They applied constructive dynamic programming to solve the OCDD problem. Both the generation cost and the ramping up and down cost (Tanaka, 2006),

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