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Steady-State Real-Time Optimization using Transient Measurements

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Abstract

Real-time optimization (RTO) is an established technology, where the process economics are optimized using rigourous steady-state models. However, a fundamental limiting factor of current static RTO implementation is the steady-state wait time. We propose a "hybrid" approach where the model adaptation is done using dynamic models and transient measurements and the optimization is performed using static models. Using an oil production network optimization as case study, we show that the Hybrid RTO can provide similar performance to dynamic optimization in terms of convergence rate to the optimal point, at computation times similar to static RTO. The paper also provides some discussions on static versus dynamic optimization problem formulations.

Keywords: Real-Time Optimization, steady-state optimization, dynamic models, production optimization, hybrid RTO

1. Introduction

Industrial processes usually consist of many operations and various components that have their own objectives and complex interconnections with other components. The safe and optimal operation of such large and complex processes requires meeting goals and objectives in different time scales ranging from planning and scheduling to fast corrective actions for regulatory control. Realizing all the goals and constraints as a whole can be a very challenging and unrealistic task. Thus the operation of any process is typically decomposed into various decision making layers [1, Ch.10], [2]. Such a hierarchical implementation is a widely accepted industry standard [3] and is also well studied in academic literature under the context of plantwide control, see for e.g. [4], [5],[6] and [7] to name a few. A typical control system hierarchy is shown in Fig.1, where the time horizon for the decisions are clearly shown for each layer. The information flow in this control hierarchy is such that the upper layers provide setpoints to the layer below, which reports back any problems in achieving this [4]. The upper three layers in Fig.1 explicitly deals with the optimal economic operation of the process. Generally, there is also more multivariable coordination as we move upwards in the hierarchy [1].

The long term decisions involve selecting an investment strategy, operation model, infrastructure etc, which is typically known as *Asset management*. Then there are decisions taken on a horizon of days such as plantwide scheduling. This is followed by decisions that have to be taken on decision horizon in the timescale of hours known as *Real-time Optimization* (RTO). This decision making step is the focus of this paper. It aims to maximize the revenue and minimize the operational costs of hour-by-hour operations, thereby optimizing the economics of the process. This is followed by a faster control and automation layer that accounts for fast corrective actions. The control layer could be broadly divided into supervisory and regulatory layers, where the objective of the supervisory layer (such as MPC) is to track the reference trajectory provided by the RTO layer and to look after other variables and constraints. On the other hand, the primary objective of the regulatory layer is to stabilize and avoid drift in the variables.

The economic optimization of any process performance is becoming more crucial in the face of growing competition. Process optimization directly enables safe operation, cost reduction, improving product quality and meeting environmental regulations and this is the main focus of the RTO layer.

A widely accepted definition of real-time optimization is that it is a work flow where the decision variables are optimized using the system model and the economic model along with the process constraints by solving some kind of mathematical optimization [8]. In order to account for process disturbances and plant-model mismatch, there has been advancements in measurement-based optimization that adjust the optimal inputs in real time, hence defining RTO as a workflow that optimizes process performance by iteratively adjusting the decision variables using

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