HD-MPC

Hierarchical and Distributed Model Predictive Control for Combined Cycle Power Plants

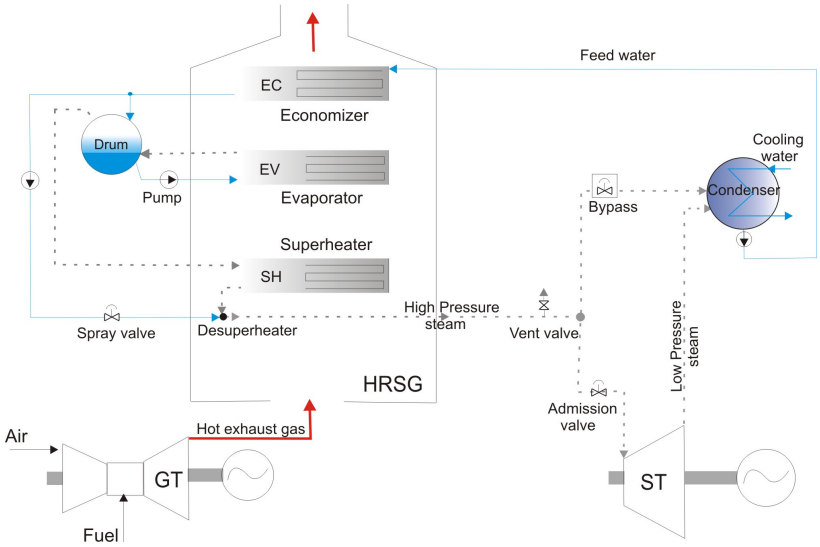
Combined Cycle Power Plants (CCPP) represent one of the most efficient, reliable and economic technologies for power generation from fossil fuels. They combine a gas turbine with a steam turbine, guaranteeing high efficiency (up to 60%) and providing a considerable reduction in pollutant emissions compared to traditional fossil fuel power plants. Moreover, they offer a high adaptability to fluctuations in the electricity demand, and are thus suitable for peak and periodic load operations. CCPPs undergo a large number of start-up and shutdown transients that are only cost factors as no electrical power is delivered, fuel is consumed, and the life-time of the plant components is severely affected by the thermal and mechanical stresses reached during this phase.

Main Challenges

The CCPP's start-up operation is relatively complex and depends on the residual heat and pressure of the plant. Optimization of the whole start-up procedure requires considering a hybrid system with both discrete decisions and continuous variables. An important phase for the start-up time is, however, the increasing load phase when both turbines are synchronized and connected to the grid and the load of the gas turbine is increased to its nominal value.

The aim of the optimization is to find a load profile of the gas turbine that minimizes the start-up time while keeping levels of mechanical and thermal stresses low in order to save life-time consumption and to avoid emergency stops of the plant.

During start-up, CCPPs operate over wide temperature and pressure ranges and the thermodynamics lead to highly nonlinear behavior. It is also important



CCCP with 1 gas turbine (GT), 1 heat recovery steam generator (HRSG) 1 steam turbine (ST)

FP7 STREP project

HD-MPC - Hierarchical and distributed model predictive control of large-scale systems

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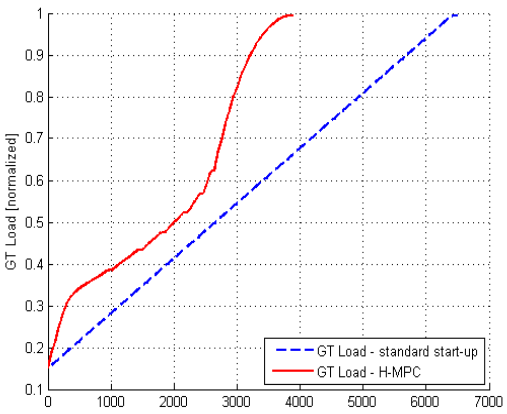
How to ...?

Control the start-up of combined cycle power plant in order to minimize time, fuel and life-time consumption.

that the model that is required for optimization can easily be deduced from general models such as design models.

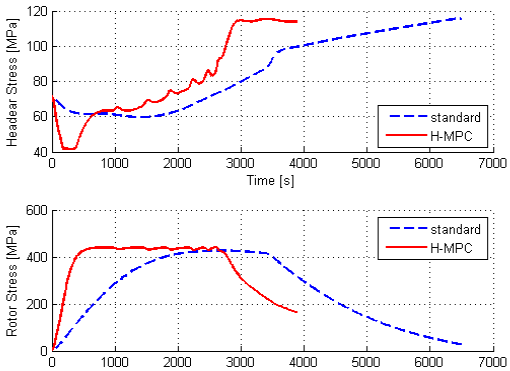
HD-MPC Solutions for CCPP

For each component of the simulation library (*Modelica ThermoPower*), a new model suitable for optimization has been designed. This makes it possible to derive the optimization model of the plant straight from the simulation model. This optimization model includes computations for the mechanical and thermal stresses of the most critical components such as the HRSG superheater header or the steam turbine.



Gas turbine load

At the higher level of a hierarchical Model Predictive Control (MPC) controller, continuous-time profiles that solve a minimal-time start-up problem are computed, at a low sampling time, by considering functions parameterized with a finite number of parameters. This trajectory is then used as a reference for the low-level MPC controller that solves an Integral-Square-Error problem on a short horizon with a higher sampling time.



Stress trajectories

Impact and Benefits

Simulations of the proposed hierarchical strategy have given confidence on its efficiency. It makes it possible to improve the start-up time while keeping the stresses under the desired level. For the considered plant, the gains are about 40% for the start-up time and the fuel consumption with respect to a linear load profile that is usually used. The hierarchical structure makes it possible to reach this performance with a computational load consistent with real-time implementation.

Main achievements

New Modelica re-usable components have been developed for modeling combined cycle power plants (CCPPs). Load profiles have been optimized based on parameterized functions. A two-level hierarchical MPC approach increases load control and improve safe start-up of the CCPP.