Making optimisation of thermal power systems possible

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With new technologies and more powerful computers, dynamic optimisation of thermal power systems has become more and more interesting to the industry. Making such optimisation possible is of great importance when designing and evaluating new systems and can also be used to optimise controllers and analyse transient behaviours. When performing such optimisation, there are high numerical requirements on the mathematical model that describes the system. In the Master's thesis "Optimisation-friendly modelling of thermodynamic properties" such models have been developed and tested in optimisation.

When performing simulation and optimisation of thermal power systems the thermodynamic properties of the working fluid of the system in many regards dictates the achievable accuracy and overall performance. In short, such models consists of numerous functions connecting different thermodynamic properties to each other. For example, if pressure and temperature is known the model can calculate the density.

Today developed libraries for thermodynamic properties in the modelling program language Modelica, following the IF97 steam table standard, has been proven accurate and very useful in such simulations. This implementation have resulted in a widespread use of the Modelica technology in the energy industry. However the IF97 model does not have support in optimisation applications, why alternative models have to be developed in order to optimise such systems.

An attempt was made to implement such a model using polynomial approximation through least squares regression. To obtain acceptable accuracy, several polynomials have to be used to model each thermodynamic property as the behaviour and characteristics of the approximated functions varies with for example the phase of the media. To make the model smooth, the different polynomials are connected via smooth step functions, that define the working region for each polynomial.

To test the models compatibility and performance in optimisation applications a test case was developed, modelling a start-up phase of thermal power

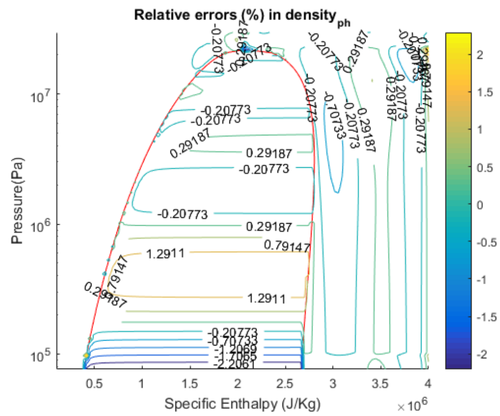

Figure 1: Relative accuracy of the density function

plant. The optimisation of this system aims at finding the optimal control inputs for the system to get to a desired working point as fast as possible. This while keeping the thermal stresses limited in order to extend the lifespan of the working components in the power plant. As can be seen from the figure below the trajectories from the optimisation well matches the trajectories using simulation. This indicates that it is possible to model thermodynamic properties in this way to be able to perform such optimisations.

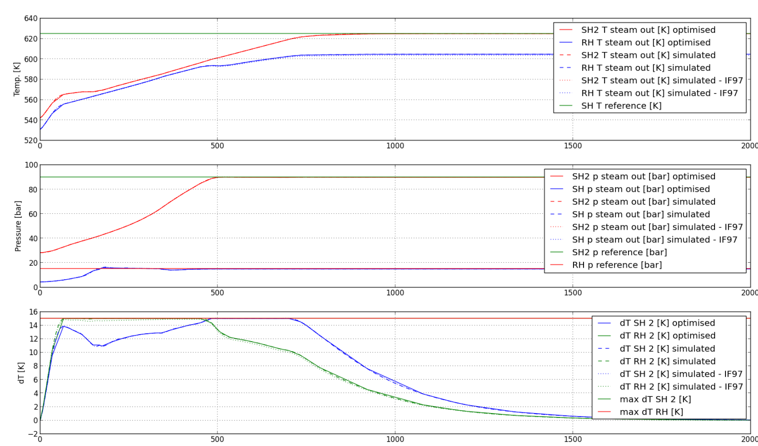

Figure 2: The optimised trajectories compared with simulation using the optimised control trajectories as input.

With a a growing part of renewable energy sources on the energy market, the role and demands on the thermal power plants are changing rapidly. The new energy situation puts high demands in the thermal power plants being able to change their loads and start and stop efficiently. In this new situation the ability to perform optimisations of this kind would be of great benefit and could aid the transition of the energy market!