CASE STUDY

THERMAL POWER LIBRARY

Improving Power Plant Operation

CHALLENGE

Why is balancing an electrical grid's energy sources important? With multiple energy sources, an energy company can garner greater stability at reduced costs. To enable a system to integrate these multiple energy sources like wind and solar, new and existing plants need to be optimized in areas focused on load change rate, start-up time, minimum load and control reserves.

In a recent research collaboration, Modelon, the University of Rostock, and Vattenfall (one of Europe's leading generators of electricity and heat) set out to improve the flexibility of a top German thermal power plant. Utilizing Modelon's Thermal Power Library, researchers developed a model that was used to: optimize start-up, investigate wear, and develop control reserve strategies.

SOLUTION – DEVELOPING, COMPARING, TESTING

The overall model consists of different sub-sections, coupled through fluid-connections and a control signal bus. Nearly 11,000 differential-algebraic equations are used to describe the system which includes about 500 thermodynamic states. To adapt the model to the specific power plant, a large set of parameters have been set - including geometric information of heat exchangers, control parameters, and char-fields of turbo-machinery. As shown in Figure 1, the entire water-steam-cycle has been modeled – which also includes the fuel and flue gas systems. The only boundaries used in the model are the input signal from the electrical grid (e.g. power plant schedule, mains frequency), the composition of the fuel and the ambient air and cooling water conditions.

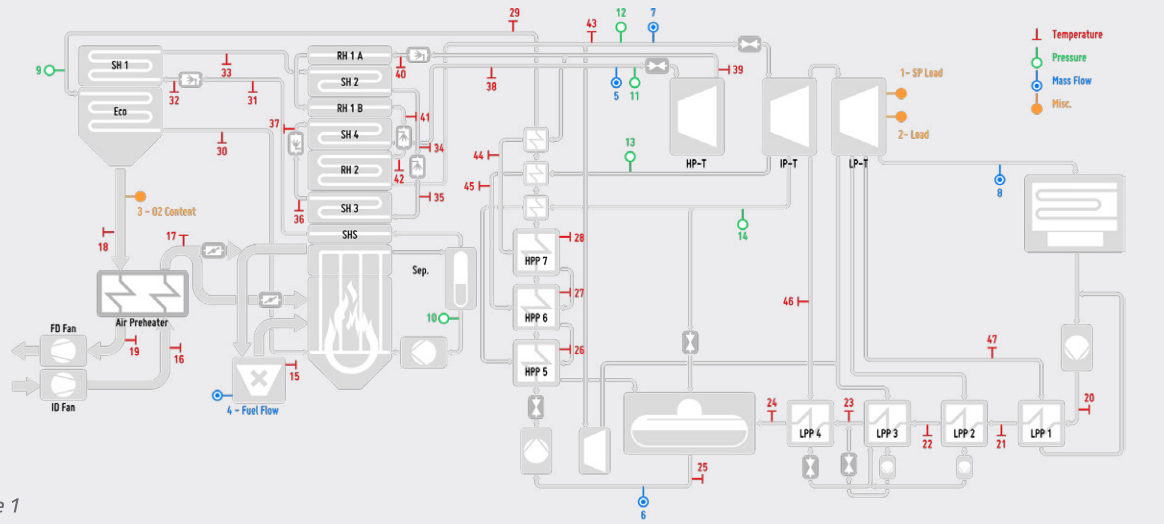

Figure 1

The model results are essential to compare the measurement data from the reference power plant. The deviation between measured and simulated give an indication of the accuracy of the model. In total, 47 reliable measurement points from the power plant were chosen to evaluate the accuracy of the model.

The scenario for qualifying primary control reserves of 4% of the nominal power output is a highly dynamic process – shown in Figure 2. To market primary control on the ancillary service market, the specific amount of additional power output needs to be activated within 30 seconds and then kept constant for another 15 minutes, followed by a deactivation within 30 seconds. The comparison of generator output between measurement and simulation in Figure 2 shows that the model can reproduce the dynamic behavior of the process very accurately. **Because the steady state values agree here, including the correctly captured overshoots, the model is valid.**

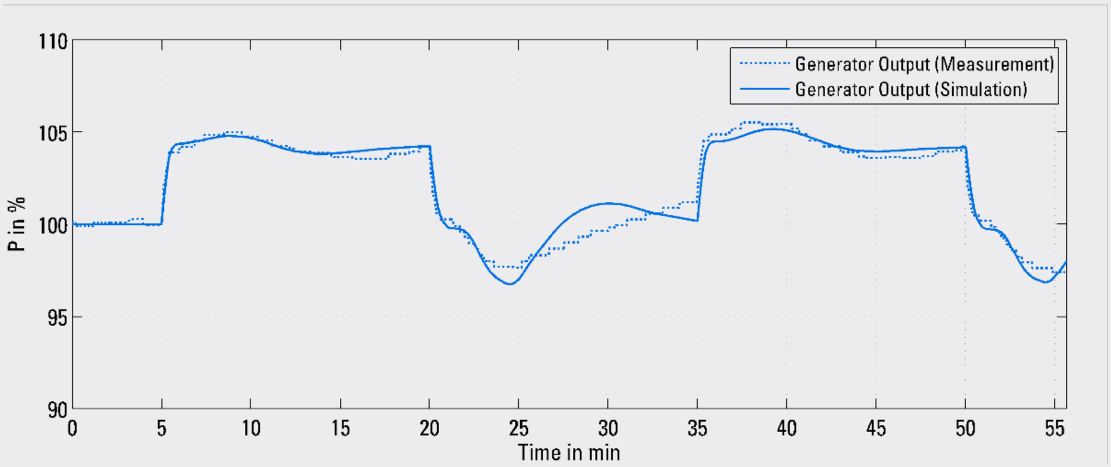

Figure 2

As the presented prequalification test for offering primary control reserves in Figure 2 has shown, the control parameters for the specific operation point and for the currently burned fuel are not tuned perfectly. After deactivation of control reserve, the power output deviates from its set point at 100% of the nominal load more than 3%, whereas the desired maximum deviation is at 1%. The test show the requirement for parameter tuning; however, fine-tuning of control parameters in field operation is rather complex and risky, as there are many sub-controllers involved for this specific scenario. In addition, a large-scale power plant is highly critical for the stability of the entire energy system and an emergency shut-down caused by adapting the wrong parameters could have severe consequences.

Utilizing the available detailed model in Modelon's Thermal Power Library, accurate parameter identification could be performed. The results from the model determined that the main block control oversteers the fuel flow too aggressively. By tuning the oversteering parameter in the block control, using the detailed dynamic power plant model, the control quality for the prequalification test increased significantly - reaching the desired bounds of less than 1% deviation from the set point.

RESULTS

With an optimized control system that has been verified in a virtual safe environment the next step is to proceed with updating the controller of the real plant. As a result, the large-scale plant has improved its primary control reserve fulfilling tougher grid code requirements and thereby improving the quality and robustness of the Germany electric energy system.

REFERENCES

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