BoilerMax
Optimize power plant start-up

ABB’s BoilerMax acts upon the set points for fuel flow, main steam flow and HP bypass valve. BoilerMax speeds up unit start while obeying the thick walled components thermal stress limits and minimizing fuel consumption.

Nowadays, the fluctuating load of wind and photovoltaic renewables require increasing flexibility of fossil fired power plants. The amounts of start-ups and shut-downs are increasing up to daily start & stop, so called two-shifting. Plant operators need to foresee the time span from firing up to synchronization in order to achieve timeliness and accuracy of the start-ups. At the same time start-ups of the boiler have to be as economic as possible.

Challenge
Boilers fire up using expensive fuels like natural gas or light fuel oil. At higher loads operators change to main fuel like coal or heavy fuel oil. During boiler warming up, the generated steam doesn’t fulfill turbine inlet parameters and is directed to the condenser.

Boiler start-ups induce significant thermal stress upon the thick-walled components of the boiler, such as headers and spherical fittings. Frequent boiler starts will increase thick-walled components lifetime consumption. Thus, the challenge is to reduce fuel costs, dumped steam and thermal stress.

Solution
The challenges mentioned above are conflicting, e.g. a faster increase of boiler load will reduce startup fuel costs and will reduce dumped steam, but it will increase thermal stress. The BoilerMax model includes the challenges as costs and minimizes the total costs for the complete start up time span.

The ABB product BoilerMax controls the lifetime consumption of thick walled components while the ABB product BoilerLife documents the lifetime consumption towards concession authorities.

Services
ABB takes over complete turnkey responsibility for engineering, installation, training, commissioning and support.
**Working principle of BoilerMax**

BoilerMax models this thermal stress together with the main boiler components and then calculates the optimum trajectory for fuel/recovered exhaust gas flow together with HP bypass settings. This optimum trajectory takes into account the optimization targets as defined together with the customer. Here costs of boiler thermal stress, start-up time, and fuel or auxiliary fuel may be weighted against income from electricity generation.

If there are measurements available for temperature differences in the boilers thick walled components, BoilerMax will use this information. If there are no such measurements available, BoilerMax will use steam parameters and their rate of change, together with material and geometry data of the thick walled components to calculate the temperature differences of the thick walled components.

BoilerMax is a non-linear, model-predictive control method (NMPC method). The main part of the BoilerMax application is a non-linear dynamic boiler model taking the steam- and flue-gas-side arrangement of the heating surfaces, headers, pipes, fittings, etc. into account. Special attention is given to those components whose stress loadings have a limiting effect on the startup operation (e.g. HP headers and hot reheat steam headers). The boiler model is of a modular design and is identified and verified on the basis of archived process data (temperatures, pressures, flow rates) which are obtained and archived during several startup procedures.

The BoilerMax model consists of the following sub-models:
- Evaporator with an integrated economizer and circulation loop,
- Super heaters,
- HP bypass, LP bypass and
- Critical components, such as the HP outlet header and the outlet header of the hot re-heater.

A special feature of the BoilerMax process model is the fact that the process parameters are internally linked and that the associated non-linear factors (e.g. water/steam table, heat transfer coefficients) are taken into account as well. Using a systematic optimization method, the optimization goals can be weighted individually and the process-specific limitations (e.g. adherence to steam temperature gradients or the ΔT limit values of thick-walled components) can be easily adjusted to the current requirements whenever necessary.

The BoilerMax process model tuned to actual process data can first be used for offline optimization runs that will reveal the existing potential for improvement - without yet being utilized for feedback control of the plant.

The boiler start-up optimization is based on a cost function that is defined together with the customer.

The startup costs consist of the consumption of fuel/auxiliary fuel, auxiliary power and auxiliary steam during the startup which starts e.g. with „Fire ON“ (light on) and ends with „HP Bypass Closed“.

In most practical cases, a minimum start-up time should be the main objective, since this ensures that the operation with the best yield is reached as fast as possible.

Using an optimization objective as described above, it is possible to compute optimized set point control functions for the relevant variables:
- Fuel/recovered exhaust gas set point,
- Main-steam pressure set point and/or position demand for the HP bypass and
- Steam temperature set points (HP boiler outlet and re-heater outlet), if relevant.

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**Basic principle of the BoilerMax application**

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**Optimization Goals**

- Optimized setpoint and inputs
- Optimized variables
- Cost function = Minimum!
ABB's BoilerMax cuts fuel used during boiler starts by up to 20% at an E.ON power plant in Ingolstadt, Germany.

1 The plots above demonstrate the BoilerMax performance. In an early start-up phase BoilerMax demands much more steam flow through the HP bypass in order to transport the combustion heat to the thick walled components. After 40 minutes the thermal stress limit is reached and the HP bypass flow is slightly reduced. During 40-50 minutes after ignition the fuel is reduced, but still life steam temperature increases quickly. The start with BoilerMax is over 20 minutes quicker than the traditional start. | 2 E-ON power plant, Ingoldstadt, Germany

The model is modular. The sub-models represent the modeled components and measurements. It allows the inclusion of tailor-made parts to take the customer-specific configuration into consideration, e.g. to incorporate new measurements or set-points, or, as required in the case of a HRSG, to use a gas turbine as heat source instead of/in addition to a combustion unit.

The BoilerMax software may be implemented in two versions:
- Offline optimization of the boiler start-up procedures as a pre-optimization. Ahead of an actual startup of the plant, the optimization is started to calculate the shortest start-up time span and other important parameters. The offline calculated trajectories for steam pressure, steam temperature, and fuel/recovered exhaust gas flow may be used for the real plant start-up. In this version BoilerMax will not react on disturbances, e.g. burner failure.
- The second version is a repeatedly working closed loop controller (model predictive controller) running during the boiler start-up in real-time and reacting on disturbances. New set point corrections are calculated for the DCS set points for steam pressure, steam temperature and fuel/recovered exhaust gas flow repeatedly.

Benefits of BoilerMax
- Shorter start-up and shut-down time reduces fuel consumption
- Faster load response to load dispatcher delivers advantages in energy trading
- Explicit consideration of thermal stresses in thick-walled components, control of temperature gradients during start-up limits wear of thick walled components.
- Reproducible starts allow precise scheduling of unit start-up time.

Reference
E-ON power plant Ingoldstadt, Germany, "It shortens and optimizes the start-up phase of the unit" says Wolfang Kleinsteinbecher, director of the power plant. "We will now produce 2000 tons of carbon dioxide (CO₂) less than last year." *) That is the average CO₂ emission of 1000 mid-size cars, according to E.ON’s press release.

*) Donaukurier 24.8.2007 (translation)