Sappi Ngodwana PF boiler advanced process control

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The purpose of the Ngodwana paper mill DCS upgrade was to replace the existing system with an ABB IndustrialIT system, and to implement advanced process control.

In 1999, Sappi Ngodwana embarked on a distributed control system (DCS) upgrade project.

As the system was implemented in each plant within the mill, advanced control strategies were installed in the digester, bleach and pulverised fuel (PF) boiler plants.

The objectives of the PF boiler advanced control application were to:

- Provide more stable and reliable energy supply
- Reduce operating costs
- Minimise disturbances to the boilers
- Minimise disturbances to the energy users.

PF boiler advanced control

The advanced process control system applied on the PF boiler project is based on a multi-variable model-predictive control (MPC) package. Multi-variable MPC "knows" the dynamic behaviour and all the interactions between the process quantities, and controls all the variables at the same time, in a coordinated fashion.

This is different from traditional control (e.g. PID control), where each controller has one input and one output. The knowledge of the process behaviour is contained in the dynamic models of the MPC, while the dynamic models predict the output response to process disturbances.

Although the multi-variable MPC only controls two variables, header pressure and steam temperature, it uses a number of inputs for the model. These can be constraints, set points, disturbance feed forward signals and other process variables. The MPC controller then calculates output response, based on the control model and generates remote set points for controlled variable action (e.g. the coal feed to the boiler and turbine load) (Fig. 1).

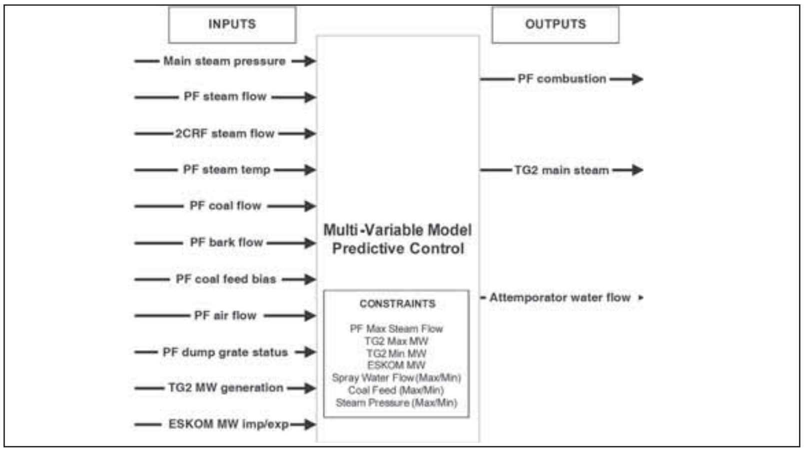

Fig. 1: Block diagram of multivariable model predict control.

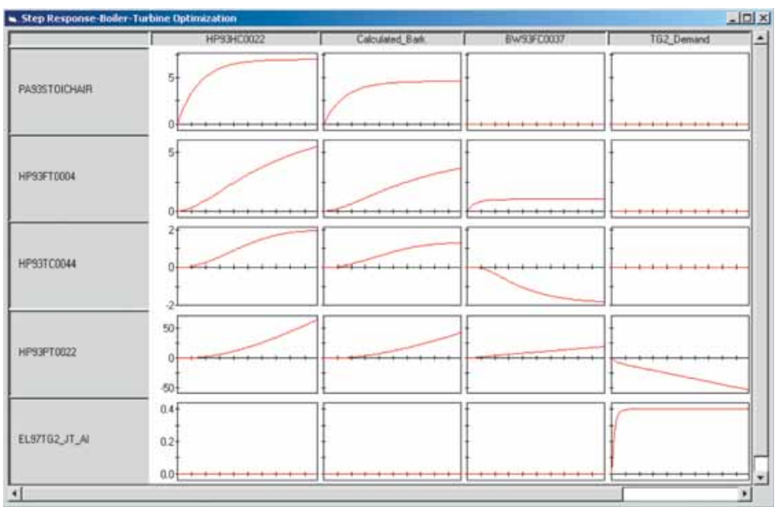

Fig. 2: Typical step response trends during modelling.

APC predicted vs actual - performance test.

	Predicted	Actual (50)% APC operation)
MW additional generation	4,5 MW	8,1 Mw
Anticipated savings/annum	R1,17m	R2,12m

Base control vs APC control - performance test

	Std deviation base control	Std deviation APC control
Steam temperature	8°C	0,8°C
Steam flow Avg	51 t/h	22 t/h
Steam pressure	88 kPa	18 kPa
Estimations based on APC in operation for 50% of boiler turbine operating time.		

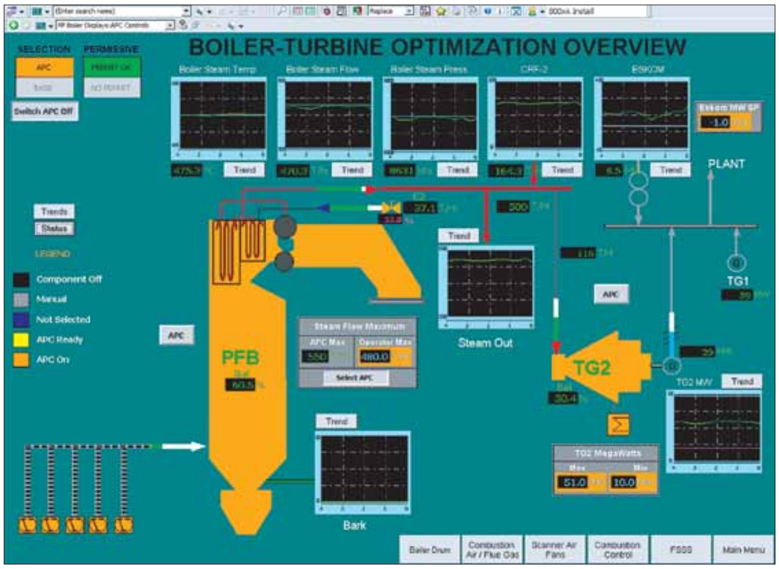

Fig. 3: Advanced process control operator display.

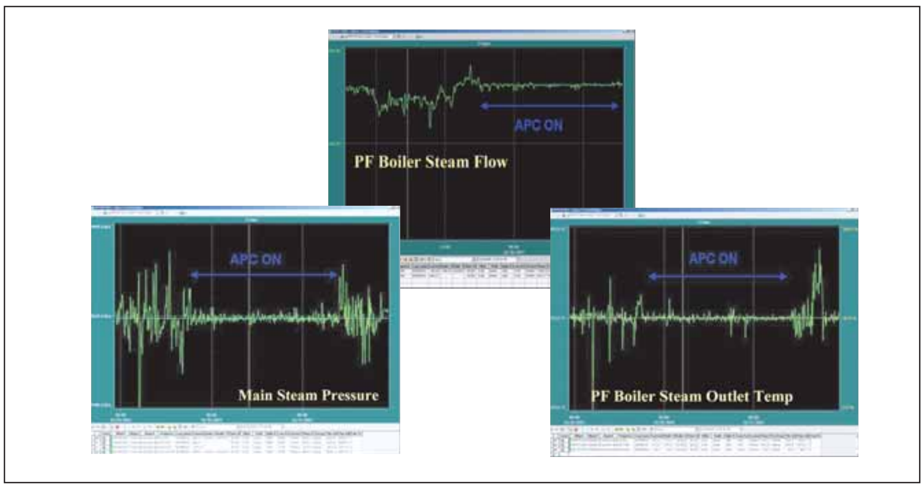

Fig. 4: Results of APC.

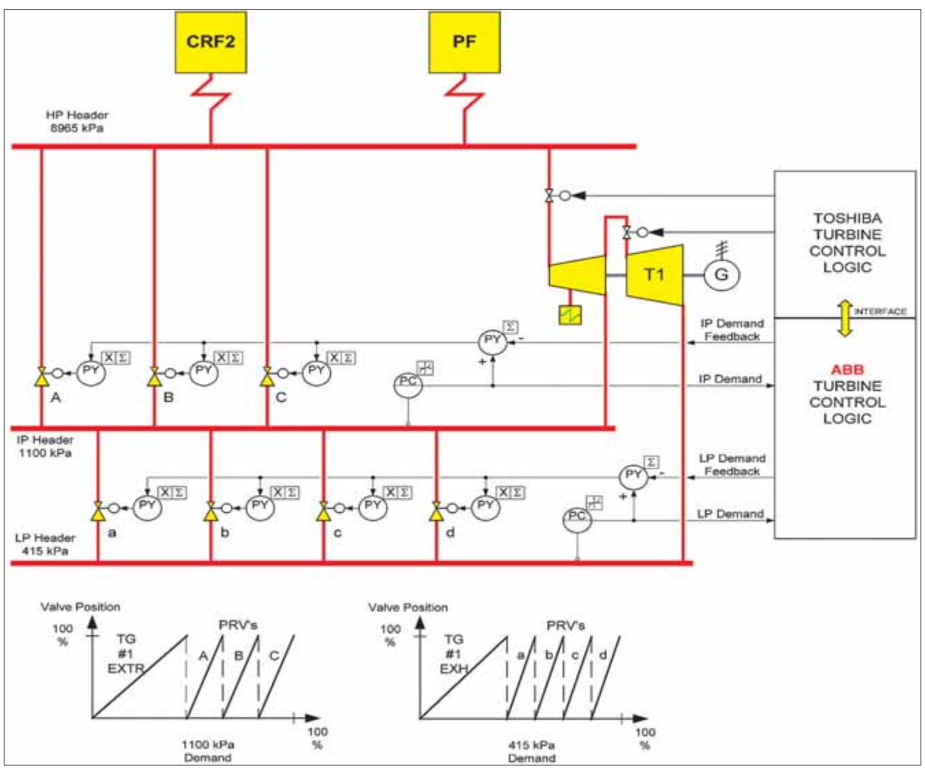

Fig. 5: Coordinated header pressure control.

The MPC makes use of soft and hard constraints. Soft constraints are settings determined by the operational staff. The MPC then optimises the controls without violating these constraints. The operator can set the soft constraints e.g. the PF boiler max steam flow, TG2 max and min MW and Eskom MW min import constraints. The hard constraints are fixed and are determined on the boiler design and safety of the equipment. The MPC will sacrifice optimum control to prevent violation of any of the hard constraints. The constraints have priority settings with steam pressure having the highest priority i.e. other constraints like MW and PF boiler steam flow can be exceeded in event of steam pressure reaching a constraint.

Set-up of model-predictive control (MPC)

The MPC is set up by modelling the response of each variable when subject to a step response of a controlled variable. e.g. the response of steam flow, pressure, air flow, coal flow is measured when a change in coal feed rate is made. A series of tests are then carried out for each input variable or disturbance variable to model the required output response of the controlled variable. This will also determine constraint values. Once the interaction between all the variables is determined, a process model is calculated and the constraints are set (Fig. 2).

The advanced process control (APC) has three main controlled variables: boiler combustion control, TG2 main steam valve control and attemporator water flow control. The APC strategy is to increase PF boiler steam flow to a maximum limit while maintaining steam pressure at set-point with TG2 and steam temperature at setpoint with spray water flow.

How MPC works

Once the models have been calculated, constraints and set points are set. The advanced control application is initiated. The APC will initialise all the values, and checks interlock status for advanced control. If all the interlocks and constraints are healthy, it will allow the operator to switch the APC control on. The operator then selects the three control elements (coal feed rate, TG2 load and attemporator water flow) for advanced process control (Fig. 3).

The APC controls the PF boiler main steam header pressure. In a condition, where the plant is steam limited, the APC will bring the boiler up to the maximum steam flow constraint. This is done by increasing/decreasing the combustion controller which adjusts the coal feed and air supply for efficient combustion. At the same time, the TG2 control is increased or decreased to maintain main steam header pressure on set point. This control will also

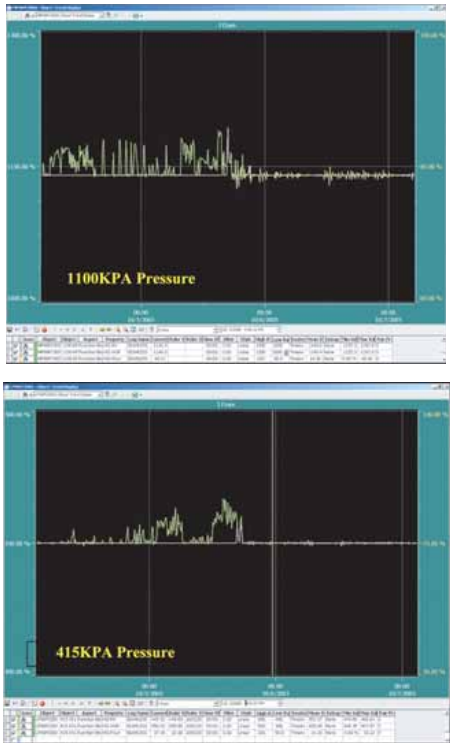

Fig. 6: Stability of the steam pressure.

impact the combustion control in event that max or min steam pressure constraint is met, as steam pressure control has highest priority. When the boiler has more steam available than the requirement of its users, the "extra" steam will be used to optimise the amount of energy generation from the TG2.

The spray water flow controller adjusts the spray water flow, based on steam flow, steam pressure and dump grate status, or combustion increments.

The combination APC control results in very steady boiler firing conditions. Main steam pressure fluctuations are minimised and steam temperature stability enables the operators to increase the steam temperature set point by 5°C, which results in more power generation from the turbines with the same amount of steam.

Results of APC

Since commissioning the APC, the boiler and turbine operation has stabilised (Fig. 4). Indications are that the system will exceed predicted savings in terms of additional power generation for the same steam flow.

The stability of steam pressure, flow and temperature cannot be quantified, but will benefit overall mill operations, and the "life" of the PF boiler.

Coordinated header pressure control.

Combined with the APC control is the co-ordinated steam header controller (Fig. 5).

The purpose of this control is to maximise power generation and steam usage through TG1 and minimise pressure reduction valve usage.

How it works

The co-ordinated pressure control uses a single pressure transmitter and controller for each main header pressure control (1100 kPa and 415 kPa). Operating as a split range controller, it adjusts the TG1 steam valves in order to maintain pressure setpoint. If TG1 control valve reaches a maximum value, then the pressure reducing valves are brought into operation one by one to maintain the header pressure control.

By maximising use of TG1 as the supplier of steam for process operations, TG1 power generation is always maximised while energy losses due to pressure reducing valve usage is minimised. The stability of the 1100 kPa and 415 kPa steam pressure (Fig. 6) and temperature cannot be quantified but will benefit mill overall operations.

Acknowledgement

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