Innovative Boiler Control Strategy for the E.W. Brown Unit #3.*

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ABSTRACT

E.W. Brown Unit #3 is a 495 MVA coal fired unit. After a number of low NOx control enhancements to meet the Clean Air Act requirements, the unit began to experience a noticeable increase in firing system lag time and degradation of dynamic capability. The unit was continuously swinging pressure and the operators were constantly taking the boiler off load dispatch. This seems to be quite common after low NOx retrofits.

The paper describes a new Boiler Master that was first developed for E.W. Brown Unit #3. It combines the traditional benefit of throttle pressure firing (return to the throttle pressure setpoint) with the traditional benefit of drum pressure firing (dynamic stability). The new Boiler Master consists of a throttle pressure controller (reset action plus feedforward signal) working in parallel with the drum pressure controller (proportional and derivative action). The throttle pressure controller dominates steady state/slow transients while the drum pressure controller provides most of the dynamic response and anticipation. Thus, separated in the time domain, the controllers do not interact.

This new arrangement is more stable than the traditional throttle pressure firing strategy. When compared with the alternative method based on the drum pressure firing (Direct Energy Balance), the new strategy was found to be much simpler and easier to tune. A similar strategy was recently used with great success for Tyrone Unit #3. This article should be of interest to coal fired subcritical unit owners because it offers a quick and inexpensive solution to pressure stability problems.

* Dedicated to the memory of Herb Gery, former L&N boiler control specialist.

INTRODUCTION

The Innovative Boiler Control Strategy (the Strategy) described in this paper is actually a combination of well known approaches. The Strategy was gradually developed as a result of a 20+ year search for a better Boiler Master. In 1985 we thought we had found the perfect solution with the DEB-400 control strategy. However, problems quickly developed. L&N went out of business and the DEB-400 control strategy could not be replicated easily or legally on other DCS platforms. A minor problem also existed - DEB-400 was cumbersome to tune.

As a result, we searched for a simpler firing rate strategy that would use drum pressure as a process variable, a strategy that could capture most of the DEB benefits, be portable to any DCS platform, be easy to tune, reliable and inexpensive.

WHAT IS SO SPECIAL ABOUT DRUM PRESSURE?

The idea of using the boiler drum as a calorimeter is not new. This concept has been in commercial use since at least 1957. Basically it states that the derivative of the drum pressure is an excellent real time indicator of the required heat input to the boiler .

Going even further back, prior to the development of superheaters, we find that all boilers were controlled by the drum pressure. The boiler master of old was basically a Proportional plus Integral (P+I) drum pressure controller and it worked very well.

Burns and Roe personnel have had firsthand experience with control systems for marine boilers built around 1950. Most of them were pneumatic systems with a P+I drum pressure controller assisted by a steam flow feedforward signal. The boiler master drove the fuel oil control valve directly, without the benefit of a fuel flow measurement. There was no gain compensation for the number of burners in service. It was a fairly crude setup. All firing rate errors had to go through the process (i.e. drum pressure upset). Nevertheless, because of the robustness of the drum pressure signal, this arrangement supported an amazing ramp rate of over 200% MCR/Min.

DRUM PRESSURE vs. THROTTLE PRESSURE as a CONTROL INDEX.

There are a number of reasons why drum pressure as a control index is far superior to throttle pressure:

- Drum pressure as a function of the energy balance is represented by a first order lag, whereas throttle pressure is represented by a third order lag.
- We think that a standard PID algorithm cannot execute its derivative function properly on a third order process feedback such as throttle pressure.
- Drum pressure reacts faster than throttle pressure to the heat input changes (up to 45 seconds faster). Faster feedback improves control loop stability. Since drum pressure reacts faster, its use as a feedback is better for boiler stability.
- Changes in drum pressure are linear with changes in energy balance. Therefore the proportional action (P) of the drum pressure controller will be accurate in restoring balance.
- Changes in throttle pressure are non-linear with changes in energy balance. If, for example, steam flow increases by 5%, there will be two major components in the throttle pressure reaction: a pressure decay proportional to the 5% change and a one time pressure

decrease due to a 10% increase in the pressure loss across the superheater. Both components are of the same sign and together represent a non-linear, exaggerated response to the change in steam flow. Therefore the proportional action (P) of the throttle pressure controller will not be accurate in restoring balance, resulting in instability.

There is one good reason why most boilers are still fired by throttle pressure. To the customer, throttle pressure is the final, visible product. This is what impacts the steam turbine performance. Drum pressure is an intermediate product, a work in progress. It is not good enough to control drum pressure alone. One has to stabilize and maintain as constant throttle pressure as possible.

Throttle pressure equals drum pressure minus piping losses (losses vary as a square of the steam flow). One has to maintain dynamic stability using drum pressure in real time while applying steady-state correction for throttle pressure. It is not hard to achieve just dynamic stability using drum pressure control. The problem is how to implement the necessary correction for throttle pressure without introducing dynamic instability.

FIRST TRIAL: CASCADE APPROACH

A PID drum pressure controller with its set point driven in part by throttle pressure controller was used at the Newport Power Station (Australia) in 1999. The first attempt was a pure cascade approach which proved to be unstable. We ended up programming the drum pressure set point as a function of the unit load. The set point program had a small and slow bias from the throttle pressure controller.

We achieved some amazing results for the Owner (Ecogen) just before they sold the unit. The boiler was on automatic control from 2% gas flow and 200 psig drum pressure. Ramp rate of 45 MW/min for this 500 MW gas fired unit was demonstrated to Ecogen.

Ecogen told us after one demonstration (two ramps, 30 minutes in total) that they just made a profit of A$500,000. They proved to the Victoria grid that due to the unit size and ramp rate, they indeed could control the grid price. At that time, the power in Victoria was sold in 5 minute increments with prices jumping from A$17 to A$5,000 and back to A$17 every five minutes.

For details see George Y. Keller, Burns and Roe, “Strategies for the Open Power Market”, Proceedings of the American Power Conference 2000, Chicago, Illinois, April 2000.

Looking back, it is clear that a sophisticated, high performance system was produced that required a lot of initial fine tuning and served the needs of, perhaps, a unique client who needed a very high ramp rate. Not everybody would be prepared to pay for 3 months worth of fine tuning to maximize ramp rate. For the average power plant owner, we needed something simpler, requiring less tuning, and cheaper.

SECOND TRIAL: NO THROTTLE PRESSURE CORRECTION

PID drum pressure controller without any throttle pressure correction was used at the Eagle Point Cogeneration Plant, Westville, NJ in 2000. Previously, each of the two HRSGs working on a common export steam header was controlled by a header master. With a header time constant of 12 minutes, this approach was marginally stable even when facing small upsets. Large upsets caused severe instability and the loss of both boilers. Clearly, the traditional approach with a header master did not work. It resulted in a complete export steam to refinery failure averaging once every three months.

After one particularly bad export steam header failure, we received a contract to effect control improvements. We implemented a drum pressure based Boiler Master for each of the two HRSGs, without any correction for the header pressure. This setup was very stable, without interaction, or swapping of loads.

As a result, the steam host (refinery) ceased to experience severe upsets. The annual benefit was in the millions of dollars. Additionally, the steaming rate from each HRSG was increased from 425 kpph to 570 kpph.

We managed not to use any header pressure correction only because this was a constant pressure, near constant load application. Such an approach will not work for most utility plants.

THREE DRUM PRESSURE BASED BOILER MASTERS WITH A SET POINT BIAS FROM A HEADER MASTER

Drum pressure based Boiler Master was implemented for three blast furnace gas (BFG) boilers in 2001 in Michigan. Each of the three BFG boilers working on a common steam header had its own drum pressure based Boiler Master. We also had a set point bias from a header master**.**

The boilers were very stable with no interaction and no swapping of loads. Header pressure was either stable with slow recovery or marginally stable with fast recovery. We could not bring ourselves to turn over to the client a marginally stable header and insisted on a stable header with slow recovery.

We found this approach was not acceptable and did not implement our strategy. However, we learned much from this experience.

THREE DRUM PRESSURE BASED BOILER MASTERS

A drum pressure based Boiler Master was implemented for three HRSGs firing variable BTU gas at 600 MW Texas City Combined Heat and Power Plant in 2004. We did not use any throttle pressure correction because this was a constant pressure, near constant load application. HRSGs were stable firing variable BTU gas. The client was satisfied with this solution.

E.W. BROWN UNIT #3

E.W. Brown Unit #3 is a 495 MVA coal fired unit. After years of low NOx control enhancements to meet the Clean Air Act requirements, the unit began to experience a noticeable increase in firing system lag time and degradation of its dynamic capability. The unit was continuously swinging pressure +/- 100 psi even with the boiler master in manual. With the boiler master in automatic swings of +/- 200 psi were common. As a result the operators were constantly taking the boiler off load dispatch.

We were asked to evaluate the problem and come up with solutions for the Unit (tuning, etc) so that it would remain on load control until the DCS upgrade scheduled in the next six months. We decided to run drum and throttle pressure controllers in parallel. To prevent interaction, the drum pressure controller was dedicated to real time control and the throttle pressure controller was dedicated to steady state control.

We could not do anything with the existing analog boiler control. So we designed and configured a new Boiler Master in the existing DCS-based Data Acquisition System. The patch was connected to the existing Bailey analog boiler control system current-to-voltage converters.

The design of the Boiler Master combined the traditional benefit of throttle pressure firing (return to the throttle pressure setpoint) with the traditional benefit of drum pressure firing (dynamic stability). The new Boiler Master consisted of a throttle pressure controller (reset action plus feedforward signal) which is biased by the drum pressure controller (proportional and derivative action). The throttle pressure controller dominates steady state/slow transients while the drum pressure controller provides most of the dynamic response and anticipation.

Satisfactory response and stability were achieved with a long derivative time – three minutes. The operators had more confidence in the boiler control and they stopped taking the boiler off load dispatch with subsequent savings to the owner.

Since then, the owner installed a new DCS and is somewhat dissatisfied with its performance. He is considering the re-establishment of our Boiler Master design.

TYRONE UNIT #3

The boiler master strategy first developed for E.W. Brown Unit #3 was recently used with great success for 75 MW Tyrone Unit #3.

A new Boiler Master was designed and configured in the existing Bailey boiler control system.

The new Boiler Master consisted of the following:

- feedforward signal (primary air demand as a function of the steam flow, calibrated for 4 and 3/2 mills in service);

- bias from the throttle pressure controller (reset action only);
- bias from the drum pressure controller (proportional and derivative action only).

After a low NOx retrofit, the traditional throttle pressure firing strategy had stopped working for Tyrone Unit #3. The unit was running for years with the boiler master in manual . Even in manual the unit was experiencing a load swing of +- 7% MCR (+-5 MW).

Our tests indicated that throttle pressure responded to changes in the boiler master with a lag of five to six minutes. Our opinion is that this is due to the large thermal storage of the unit (relatively large drum) and the typically sluggish response of the low NOx firing system. We achieved satisfactory response and stability by using a drum pressure controller derivative time of five minutes.

We had to be careful with the reset action in the throttle pressure controller. Aggressive reset led to a quick throttle pressure recovery but resulted in a significant throttle pressure roll. At the moment, 0.04 repeats/minute reset is being used. This results in an acceptable 4 psi pressure roll with a peak to peak time of 22 minutes.

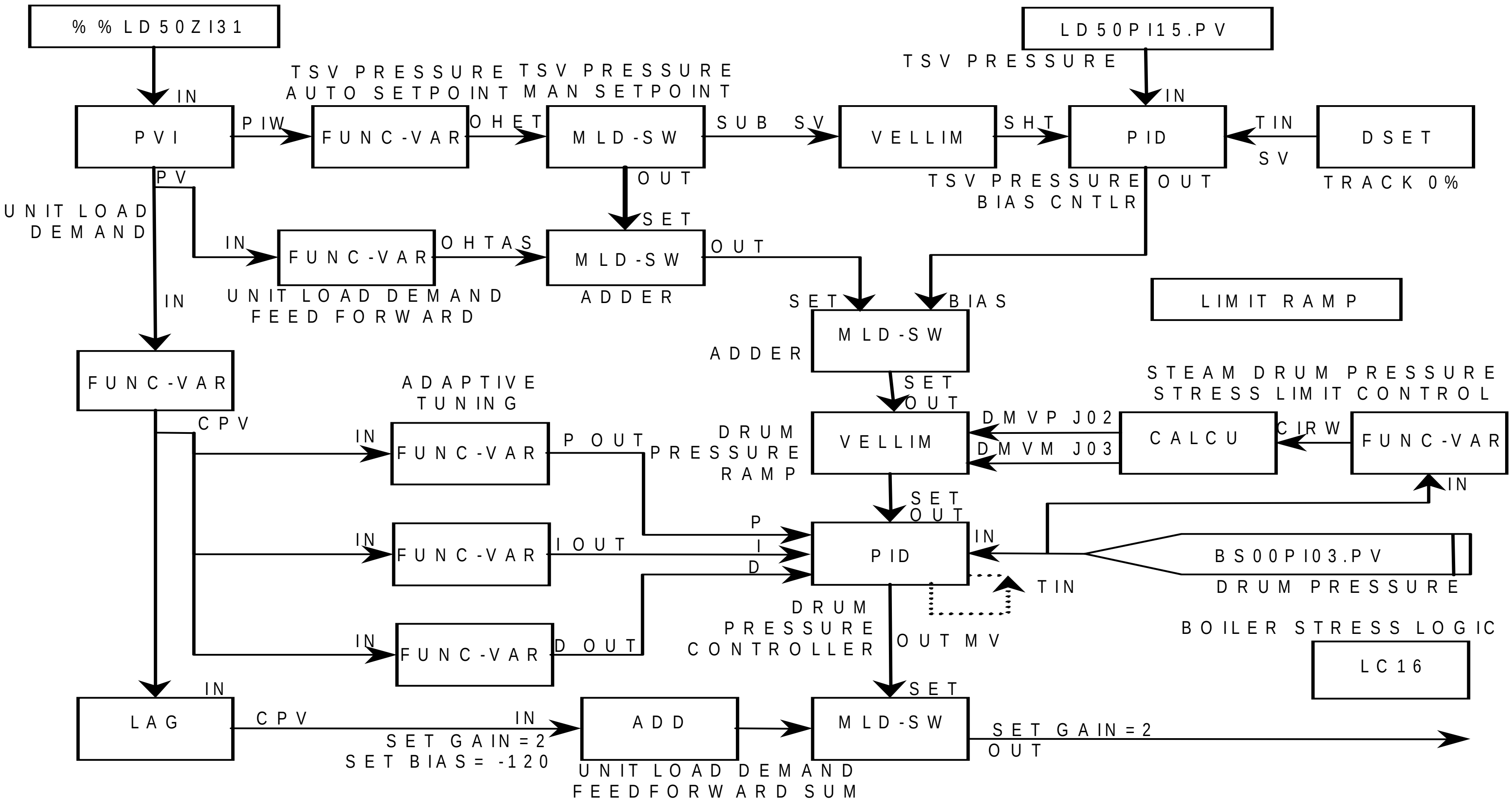
CONCLUSION

The new Boiler Master design, described in this article, uses a throttle pressure controller for steady state/slow responses and a drum pressure controller for dynamic response and anticipation. Separation of the two controllers in the time domain proved to be a worthwhile innovation for drum units with stability problems.

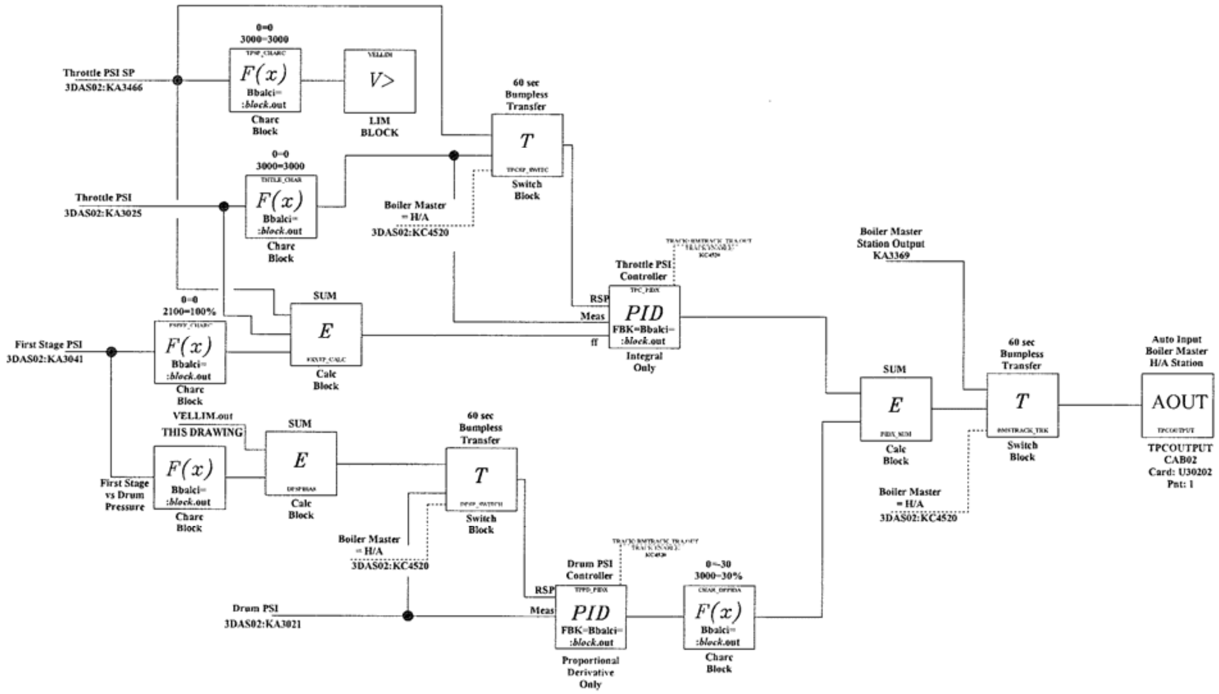
Our Boiler Master Strategy is effective for boilers with Low NOx burners experiencing stability issues. The flexibility of our concept is proven given the variety of applications it has been successful in, saving clients money, but more importantly, producing real income.

Attachments:

1. Front End SAMA Logic for Newport
2. Boiler Master for E.W. Brown Unit #3



Front End SAMA Logic for Newport



Boiler Master for E.W. Brown Unit #3