Burns and Roe

Miscellaneous Comments on Boiler Control Tuning

Presented at the 9th Cogeneration and Independent Power Congress

George Keller, PE
Senior Consulting Engineer
Burns and Roe
Oradell, NJ

Burns and Roe Enterprises, Inc.

INTRODUCTION

This article is on boiler control tuning, a task that is important to do and difficult to perform**.**

Why is tuning of the boiler control so difficult?

Because it is essentially one large, interactive, non-linear control loop, which does not lend itself to "automatic" tuning.

Why is good tuning of the boiler control so important?

Because it impacts the boiler and turbine efficiency, unit ramp rate and generation error, unit turn-down (low load operation), and unit availability (ability to survive process upsets and equipment failures).

Can you improve boiler operation through tuning alone?

Yes. If the practitioner of this art is competent, boiler control tuning can cover-up a multitude of sins. However, it is best to combine tuning with a new control system, appropriate control strategies, good measurements and small deadband actuators.

BASICS

1. A boiler control system must be tuned from the bottom up. One must start with control drives and valves and work one's way to upper loops and feedforwards.

2. All measurements must be solid and beyond suspicion. Use of triple-redundant transmitters for drum, throttle and first stage pressures is highly recommended. Four transmitters should be used for drum level and furnace oxygen measurements.

3. Superheat and reheat thermocouples should be checked for proper response. At 80% load one should increase the spray valve position 5% as a step function. Observe spray and final temperature trends. Thermo-couples with temperature trends exhibiting time constants in excess of 30 seconds should be removed and checked for good contact with the bottom of the well.

4. Check and make sure that a 1-2% increase in the control variable (valve, drive) has a fast and repeatable effect on the process variable (feedwater flow, gas flow, air flow, etc.). If by looking at a trend you can see 3% to 5% deadband in the control variable, tuning of that loop must be

stopped and the valve or drive repaired. No amount of upper loop tuning will fix a 5% deadband in the lower loop.

5. It is highly desirable to have as fast a measurement and control response as can be tolerated and practicable. In many cases, control valve stroking speeds of 2-3 seconds are required. This improves the stability and quality of control of the loop under consideration. However, if this loop is affecting and upsetting other loops, a compromise must be reached. In some cases an excessive speed (one example would be ID Fan inlet vanes) can cause major equipment damage, so good engineering judgement is required. However, a general rule remains: one should increase the speed of response as much as possible.

6. It is desirable to use as little proportional gain, reset and derivative as necessary to achieve adequate quality of control. When a compromise must be made, one should favor stability over quality of control. A common error is to use excessive reset action, which is deadly for most control loops.

7. Feedforward signals are essential in achieving good stability and quality of control. The necessary influence of the feedforward signals should be calculated from the steady state tests. No more than 80% to 90% of the actual influence should be used for control purposes. Example: if SH spray temperature set-point changes 15 Degr F for 100 psi of the first stage pressure, use only 12 to 13 Degr F/100 psi as a feedforward signal. Let the feedback control take care of the last two Degr F. Otherwise, you could be introducing instability.

8. Adaptive tuning is essential in achieving good stability and quality of control. It means that every critical loop must be tuned at 5 different load points. Availability of adaptive tuning must be considered when selecting a control system.

9. Tuning takes time and patience is one of the most important ingredients in its success. After preliminary tuning (making sure each loop operates by itself) is completed, the time consuming effort of fine tuning or making sure all loops work together, throughout the load range and under all foreseeable upsets begins. Again, this is the time for good engineering judgement and acceptable compromises. Tuning is the art of selecting acceptable compromises.

DRUM LEVEL

The degree of drum level tuning difficulty depends on a ratio between the boiling water storage and steam flow. Tuning of drum level control on a 600 MW natural circulation boiler with a steam driven feedpump is extremely difficult due to the drum level instability. Drum level control on a 30 MW heat recovery boiler is much more forgiving. While it is hard to generalize, here are some common guidelines.

1. Boilers with small relative drum size might need full-time three element feedwater control. This would require extended range feedwater flow measurement (two stacked transmitters.).

2. Stability of any boiler will benefit from lagging steam flow signal (first stage pressure) by 15 to 45 seconds. The best lag time must be found by trial and error.

3. A cascade arrangement (level controller as an upper loop with a steam/ water flow ratio controller as a lower loop) should be used. The most important thing is to keep the steam/water flow ratio in balance. This is the case for using high reset rates. Reset rate for the level controller should be on the order of 10 minutes per repeat. Proportional gain for the level controller should be as little as possible. Balancing the steam and water flow is all important, bringing the water back to the normal level as quickly as possible is not only unimportant but also counterproductive. In the extreme, overfeeding the boiler can cause severe temporary level “shrink” (the new water is relatively cold) followed by a severe swell (the new water is getting heated up) and high drum level trip.

4. Adaptive tuning of the level controller is essential in achieving good stability and quality of drum level control.

5. Tuning of transition through minimum recirculation flow of steam driven BFP can be very challenging on large utility boilers but must be done if a minimum unit load of 15% MCR is desired.

6. It pays to get the drum level control tuning as perfect as possible, especially on large utility boilers. Drum level control instability will de-stabilize an entire boiler. Usually the unit ramp rate, minimum load, and runback capability (staying on the line after an upset) are determined by the drum level stability.

STEAM TEMPERATURE CONTROL

One of the most important requirements in achieving good steam temperature control is to have fast and accurate steam temperature measurements. Type E thermocouples in a stainless steel sheath will satisfy their requirement provided that they are in good contact with the bottom of the thermowell, without such intermediaries as rust or dirt. While a grounded junction is desirable, it is not essential if prevented by the T/C input card manufacturer. The time constant of the thermowell is dominant over the time constant of the ungrounded thermowell. It is important to obtain the fastest thermowell that steam condition will allow on the new boilers. If the existing thermowell is too massive, it does not pay to replace it. Instead it should be compensated to some extent by a derivative action of the temperature controller.

Best results are obtained with a cascade arrangement: spray temperature controller as an inner loop, final temperature controller as an outer loop.

The spray temperature controller set point should have a feedforward component as a function of the first stage pressure. If spray water supply pressure changes dramatically, one must compensate for it via an adaptive gain in the spray temperature controller.

The final steam temperature controller must be tuned at five load points (adaptive tuning).

Tuning of the superheat temperature controller must be stable or else the entire boiler will be swinging with 4 to 5 minutes peak-to-peak period

FUEL FLOW

This loop should be tuned conservatively. Remember, if it is done correctly, one only needs to move the fuel valve 2% to 3% per minute. One should not get preoccupied with maintaining exact throttle pressure: it is impossible while on load control. During the first 30 to 90 seconds after a load change, the required energy comes from the storage (boiling water in the drum); a change in the firing rate has no effect on throttle pressure.

Fuel flow loop cannot be made faster than air flow loop (unless one uses too much excess air, which is wasteful of fuel). That means that one must observe fuel and air flow trends during the numerous up and down ramps. Ideally, fuel and air flow trends should move in parallel to each other. Usually it means slowing down the fuel controller (less gain, less reset, no derivative).

Fuel flow controller must be tuned at five load points (adaptive tuning).

AIR FLOW AND EXCESS AIR CONTROL

One should not use a boiler demand signal as a set-point to the air flow controller. Instead, a boiler demand signal should be converted into an air flow demand signal via a function generator. This arrangement will take care of the oxygen curve even before the biasing action of the excess air controller is applied. Two benefits are derived from this: the boiler can run near normal even with oxygen probes out of service and the unit will be capable of higher ramp rates when the oxygen probes are in service.

Air flow controller must be tuned at five load points (adaptive tuning).

A feedforward signal from the air flow demand signal to the FD fan total position demand is very useful.

MINIMUM LOAD OPERATION

With perfectly tuned large gas/oil fired utility boiler. it is possible to be in full automatic control at 3% MCR. While we cannot recommend doing this for extended periods of time, 15% MCR as a minimum load usually is not a problem, as long as drum and heater level controls are well tuned.

RUNBACKS

Runbacks must be tuned and tried or else they better be disconnected.

It takes a lot of courage and lost revenues to tune and prove the runbacks, but without this effort a single equipment failure will trip a cogeneration plant with multiple combustion turbines, boilers and steam turbines. Some major cogeneration plants have experienced such a domino effect.

ECONOMIC BENEFITS

Good tuning provides an economic payback due to improvements in the quality and ramp rate of the load dispatch, lower excess air and higher final steam temperature.