Super critical coal fired plant requirements and the Grid Code

Paper by E.ON UK

Introduction

Super critical coal fired plant is one of the leading options for replacement of the opted out of LPCD thermal plant. Several Generators have proposals for such plants at various stages of project development. Currently plants must fulfil the requirements of the GB Grid Code. The GB Grid Code has more demanding requirements for frequency response than have previously been applied to this type of plant.

The Code requirements were not drafted with this type of plant in mind and some modifications to the Code would enable the plant design to be optimised to meet the various environmental, financial and performance requirements.

The Current Situation

The minimum requirements for Primary, secondary and high frequency response demanded by GB Grid Code are tested using a frequency ramp of 0.5Hz over 10 seconds.

The minimum frequency response requirement profile shown diagrammatically in figure CC.A.3.1 is for a generating unit which has a designed minimum operation level (DMOL) of 55% and a minimum generation (MG) 65%. The capability profile specifies the minimum required levels of primary response, secondary response and high frequency response throughout the normal plant operating range.

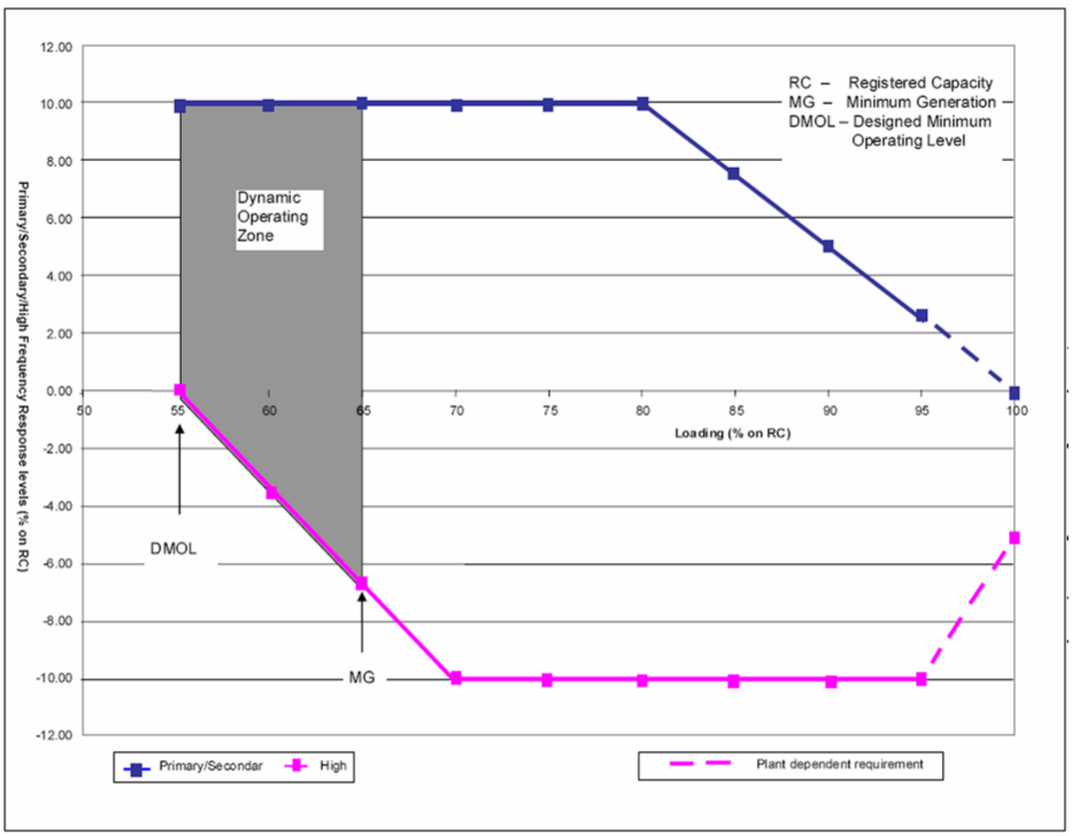


Figure CC.A.3.1 Minimum Frequency Response Requirement Profile for a 0.5 Hz frequency change from Target Frequency

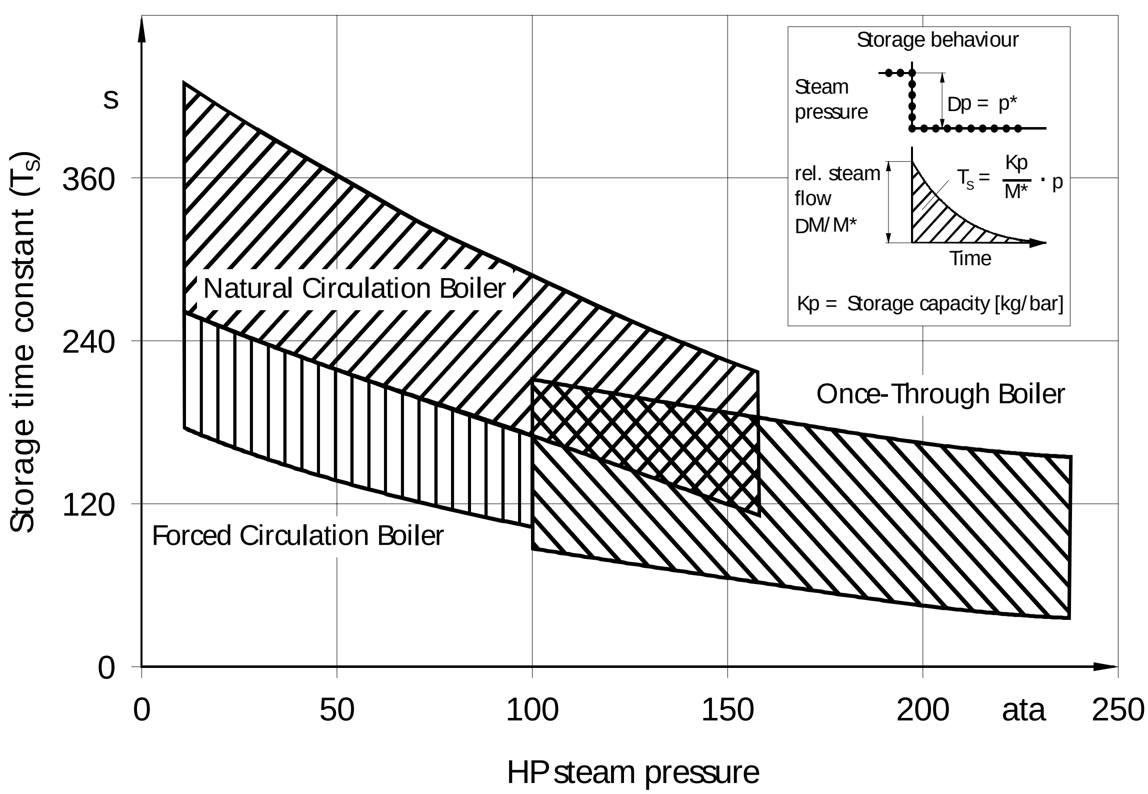
These requirements have been devised with the performance of CCGT and current drum boiler sub critical steam plant in mind. At present the GB Grid Code frequency response requirements are fulfilled by operating the sub critical drum boiler at a fixed constant pressure and the turbine inlet valves throttled. The energy stored in the boiler is releasing opening the steam turbine throttle valves in order to provide primary response. The valves are closed to facilitate high frequency response and secondary response is provided by increasing firing.

Performance Issues for Super Critical Plant

The super critical boiler does not have the energy storage advantages of the sub critical drum boiler. Current industry practice is to operate these plants on sliding pressure with throttle valves open. Frequency response is provided by interrupting the bled steam to the feed pre heating system, this technique is commonly known as condensate stop.

The super critical once-through is a very flexible boiler system since it offers optimum fuel flexibility and high efficiencies across a wide load range. This type of boiler also has an impressive loading rate giving distinct advantages for providing secondary response.

Increasing the operating pressure produces the desired cycle efficiency gains, however as illustrated in the diagram below, the stored energy is reduced as pressure increases.



For the Supercritical boiler the designed minimum operation level (DMOL) can be significantly lower than current plant capabilities and 25% of MCR is a realistic figure. However once though operation is not possible until say 40% load, at which time increased loading rates are available.

The primary response capability (P) of a generating unit is the minimum increase in active power output between 10 and 30 seconds. For the -0.5Hz change in frequency there will be load points where 10% response will not be possible and it is doubtful whether 10% could be reasonably achieved at all.

The secondary response capability (S) of a generating unit is the minimum increase in active power output between 30 seconds and 30 minutes. Loading rates are impressive after a time delay for the effect of increased firing to take effect. Providing adequate secondary response is not expected to be an issue.

The high frequency response capability (H) of a generating unit is the decrease in active power output of 10% required 10 seconds after +0.5Hz change in frequency. It is not anticipated that meeting this requirement will cause problems.

When a generating unit has responded to a significant frequency disturbance, its response capability must be fully restored as soon as technically possible. Full response capability should be restored no later than 20 minutes after the initial change of system frequency arising from the frequency disturbance.

Choice of Operating Mode

Super critical power plants can be operated in constant-pressure operation, in sliding (variable) pressure operation and in modified sliding pressure operation (intermediary operation between constant and sliding pressure operations).

The modified sliding pressure operation combines the advantages of constant-pressure operation with those of the sliding pressure mode. The ability to activate the storage capacity of the boiler by opening the throttle valves is combined with the advantages of low lifetime consumption of the plant and high part load efficiency.

For the UCPTE Grid where the frequency response requirements are less stringent (2.5% MCR), the advantages of the sliding-pressure operation prevail. For the GB case of high demands on frequency response, the constant steam pressure operation or the modified sliding-pressure operation is a more realistic choice.

Unfortunately there is not sufficient stored energy available in the boiler to meet the GB Grid Code requirements using turbine throttling alone. The situation is more acute at high loads and additional measures will be required.

LP Extraction / Condensate stop

Condensate stop can be regarded as a standard feature as it is generally regarded as the primary means of providing frequency response. It is particularly effective at high loads.

Turbine power is increased by interrupting the flow of bled steam to the LP feed pre heating system. Preheated condensate is provided from storage tanks and the interrupted flow accumulates in the condenser.

HP Extraction / Feed-water Stop

Turbine power is increased by interrupting the flow of bled steam to the HP feed heating system. This is achieved by dividing the feed-water into a partial flow which is preheated and a second partial flow, which bypasses the HP feed heaters and is then re-mixed with the preheated flow.

This HP Extraction / Feed-water stop system causes thermal stress in the boiler and should be avoided for primary response. There is the possibility that the temperature transients that would occur could trip the generating unit. The operating time required to use this feature with acceptable safeguards would be too slow for to be an advantage for primary response.

Increasing the output of the boiler

Impressive loading rates of 5%/minute are available from this type of boiler. However the reaction time of the firing system is approximately 35 seconds. The response time can be improved by firing the boiler on oil or gas directly triggered by falling frequency.

Consideration of Other Methods

There are of course a multitude of additional methods of providing the extra energy required, it is simply a matter of finding an energy store that can be converted into electricity in 10 seconds. Energy storage could be kinetic energy in a flywheel, heat in a steam accumulator, or chemical energy in a battery for example. Whilst these could be regarded as available technologies they have not previously been applied to this problem and would therefore pose an unreasonable increase in risk to the project.

Project Financing and Risk

The next coal fired power station to be constructed in the UK will be the first since Drax stage 2. It will be a major undertaking with associated project risks. In order to keep such risks under control it is important to select plant that has a proven track record. Unfortunately, experience of using supercritical coal fired plant in the way the Grid Code requires is unprecedented and there is very little practical experience to draw on. This introduces several unexpected risks to the project.

The many measures required have not been tested by operational experience. There is a real risk that relying on several untried techniques in combination could result in a shortfall and non compliant performance. The techniques employed produce temperature and pressure excursions that will reduce the life of the plant and without operational experience the effect of this is difficult to predict.

The addition of carbon capture technology particularly is going to present new challenges as it will interact with the plant's frequency response capability.

Although the supercritical boiler is an established technology the current Grid Code requirements do not allow generators to purchase plant of proven performance and this has a number of negative influences. The power industry is facing a period of expansion, order books are full and power plant builders can afford to be choosy about which projects they participate in. The current rules are presenting these projects with an increased project risk that could adversely affect the business case, resulting in suppliers simply not making the investment in new coal fired plant. Manufacturers are unable and unwilling to give performance guarantees or even to supply plant where there are uncertainties about their ability to meet the requirements

To keep project risks under control it is proposed that plant designers should be able to select plant from the market which has a reasonable chance of demonstrating proven performance which can be guaranteed by the manufacturer.

Proposed Areas Where Changes to the Grid Code Could be Considered

We suggest that a working group could be asked to consider the following:-

- Revised Definition to Facilitate Averaging
- Lower Requirement at Lower Load
- Variable Performance Requirement
- [Variable Pricing Structure – may be a BSSG/CUSC issue?]

- Relaxed Rules for Development Plant
- Any other relevant issues

Revised Definition to Facilitate Averaging
The existing minimum requirements for frequency response have been based on the performance of the existing plant which consists mainly of coal fired sub-critical boilers and CCGT plants. Owing to the difficulties in achieving this minimum profile, the requirements have now become a target. Such a target will not achieve the optimum release of energy to fulfil the frequency response objective. The way in which the requirements are defined should be reviewed. For example, specifying an amount of energy to be delivered in a specific time would allow some averaging to take place, rather than the rigid target profile that is currently used.

Lower Frequency Response Requirement at Lower Load
The supercritical plant is capable of operation at lower loads that the existing plants. It is preferable to reduce load to 25% rather than to two-shift the plant. Providing frequency response of 10% MCR at this load would effectively mean load increases of 40% which is neither practical nor reasonable.

Variable Performance Requirement
When the supercritical plant is operated at low load some recirculation is required. This mode of operation reduces the loading rate which could have an effect on frequency response. MG load with would be 25% RC with 40% RC required for full once through capability. The existing definitions of MG and DMOL adequately describe the plant operation since the plant can operate continuously ant 25% with 40% the load a which the loading rate can be increased with the activation of the once through capability.

[Variable Pricing Structure – for consideration by the BSSG/CUSC?
The frequency response of the supercritical plant is likely to be achieved by combination of techniques each with its own specific cost. The last few MW are likely to be very expensive and this is going to adversely affect the bid price for the service. Market changes may be needed to allow a staged bid. This would allow a plant to participate with a 5% response when under the current regime providing 10% would be prohibitively expensive in terms of energy or wear out.]

Relaxed Rules for Development Plant
There are no super critical plants that have demonstrated the performance requirements of the GB Grid Code. The modelling techniques readily available are not sufficient sophisticated to predict how the plant will behave either in terms of performance or lifetime consumption if the code is rigidly applied. Consideration could be give to a more relaxed compliance procedure which would give generators the confidence o proceed with what is going to be unproven plant.

Way Forward
We would welcome the convening of a Grid Code Working Group to consider the above issues, and any others considered by the GCRP to be relevant.

RJ Nicholls – E.ON Engineering
C Maxim – E.ON UK
30th April 2008