

Combined Heat and Power Systems – Design and operational considerations to get the best performance from CHP systems.

October 2014

Design and operational considerations to get the best performance from CHP systems.

As we explore in our white paper ***‘Combined Heat and Power Systems – When is CHP the right renewable energy choice?’*** there are many considerations for the suitability of CHP in any given application.



Once it's clear that CHP is the right solution, how do you get the more technical elements of specification right? And how do you avoid common mistakes to get a high performing and operationally efficient CHP system?

This white paper is designed for those at the technical specification stage of CHP design, and covers mechanical, electrical and operational considerations including:

- Design Philosophy
- Operating Strategy
- Relationship With Boilers and BMS
- Electrical Infrastructure
- G59 embedded generator regulations
- Spatial Requirements
- Acoustic Considerations
- The common pitfalls in CHP design

CHP design and specification

There are many key factors in the correct design of a CHP System and we focus on the key points here.



Design philosophy

The relationship between thermal and electrical demand is key to the correct design and specification of a CHP system.

The design of a CHP in most applications is led by the requirement for heat. A system led by the requirement for electrical demand is less common, but can be very successful if designed in the right way.

Another solution is to have a heat led, electrically capped scheme. In situations where the thermal demand may be greatly in excess of the electrical consumption of a site, there is a risk that power could be exported onto the local grid. If such export is undesirable to the client, it is possible with some CHP controllers to limit the electrical output by placing a 'cap' on it. In this situation the output will be responding to heat demand, unless the consequential production of electricity approaches the export threshold when the artificial cap will take over control.

A consideration within the design philosophy is how many hours the CHP unit needs to run per annum to fulfil the client's objectives.

“

The design of a CHP in most applications is led by the requirement for heat

”

Operating strategy

A **commercially sound operating strategy** should be based around the spark gap or rate, identified previously as the amount between the cost of gas and the cost of electricity.

Gas must be cheaper than electricity for a CHP system to be commercially viable.

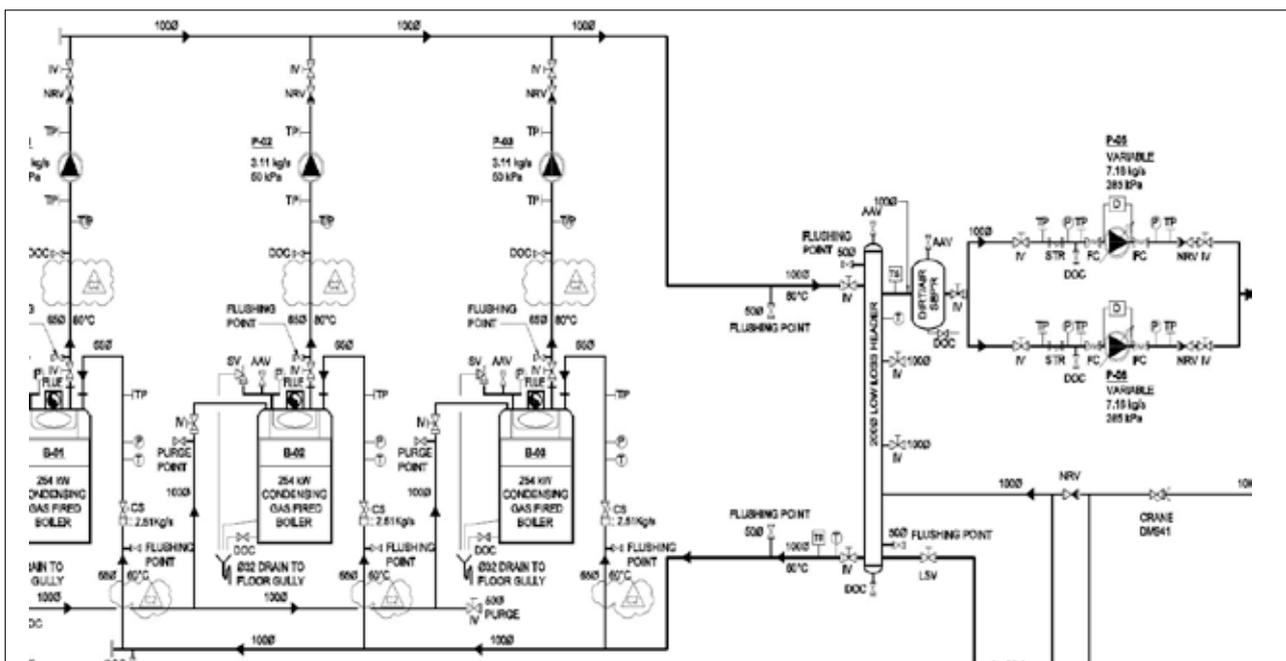
A **mechanically sound operating strategy** should take into account the facility infrastructure, and the relationship of the CHP system with both the Building Management System (BMS) and boilers.

Consideration of operating strategy and the relationship (“the marriage”) between CHP and boiler plant is an essential part of mechanical design.

Mechanical infrastructure, that is, water pipework (hydraulic arrangement) ventilation ductwork, exhaust and flue arrangements, gas supply pipe, heat and gas metering, should embrace all operating conditions.

Understanding the most common pitfalls and avoiding them at the design stage is critical. CHP is often best used in parallel with the boiler plant not in series, and CHP should always function as the lead boiler.

A CHP has a simple requirement that the returning water must be below the maximum permitted temperature value at all times. With this requirement fulfilled, the running hours of the unit will be maximised. Difficulty arises when designers are unable to meet this requirement, particularly during times of low thermal demand. Oversizing CHP plant during the selection process tends to exacerbate this problem.



Relationship with boilers & BMS.

More than 90% of operational shutdowns or failures of CHP plant are caused by bad control strategy or errors in the surrounding systems.

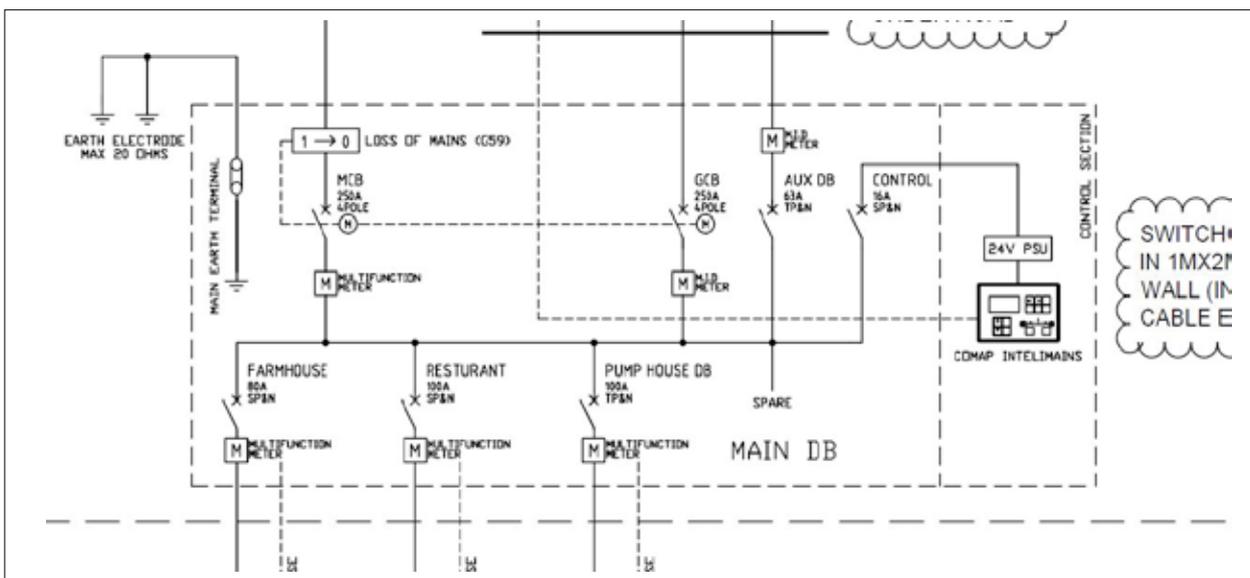
The target efficiency of a CHP system will become undeliverable if the design and installation does not encompass the correct relationship with the heating system and BMS. This is one of the greatest areas of mismanagement of CHP installations, frequently misunderstood by designers. As CHP is often procured by mechanical engineers, it is important they should take into account the electrical and controls aspects of operation.

Incorrect mechanical arrangement, such as preheating condensing boiler returns, can cause loss of performance of the plant and ultimately impact its success. To get this right, the relationship between CHP, boilers, BMS and all interconnecting or interdependent systems must be considered as one whole.

Electrical Infrastructure

A CHP system is in effect a power supply embedded within your building and connected to the national grid. There are several things that must be considered before a CHP system can be commissioned, or in other words become operational and run in parallel with the mains.

There may be inadequacies in electrical infrastructure, such as insufficient supply cable, multiple mains intakes, especially where designers have assumed CHP energy can be delivered to the entire development. This can affect the connection of the CHP system to the electrical infrastructure around it. Specific industry regulations apply to this, which are known collectively as the 'G59' regulations.



G59 embedded generator regulations

The main reason for the G59 requirements is to regulate generator applications, so that no generators are connected to the grid without the specific knowledge and permission of the local electricity authority, also known as the District Network Operator (DNO). The principle reason for this is to prevent the embedded generator from sending electricity out onto the National Grid. Recently, the G59/2 specific regulations have been superseded by G59/3.

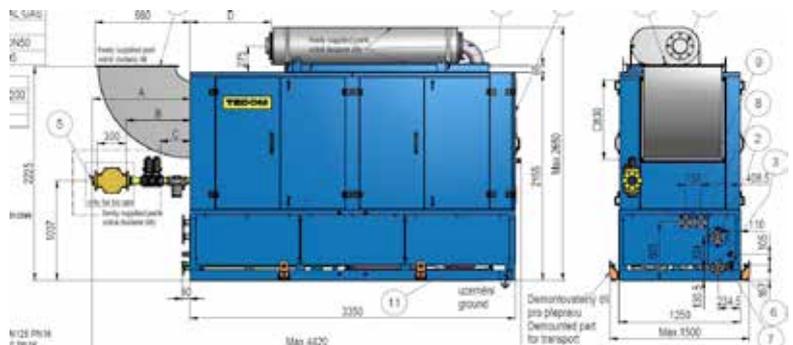
To prevent any issues with the commissioning of the system, the G59 application should be submitted as soon as possible - preferably at feasibility stage. Frequently this is overlooked, as parties involved in the process are either not aware of the requirements or assume that responsibility sits elsewhere. Unless the G59 application has been submitted and approved, the CHP cannot be commissioned. There is also a risk that unplanned costs imposed by the DNO may impact on the viability of the project.

Spatial requirements

Allocation of sufficient space is a common design oversight when specifying CHP. The Construction Design and Management (CDM) regulations require designers to 'build-in' sufficient and appropriate access all around the unit, for safe and effective operation and maintenance procedures throughout its entire life.

At some point in its service history the unit is likely to have an engine replacement. Consideration should therefore be given to the access route from a location where a delivery vehicle could park, right through the building, to the plant room where the CHP is housed.

Designers should consider that extensive future cost may be incurred by the end client, if insufficient special provision is made for the regular servicing requirements and future maintenance.



Acoustic considerations

There are three areas of consideration for acoustics:

- Breakout noise (sound that escapes from the engine package itself).
- Ventilation noise (for units that require ventilation - not all do - this is sound which escapes through the air intake / discharge ductwork).
- Exhaust noise.

All of these should be considered individually as their acoustic requirement may be different. It's common for acoustics to be greatly over specified; after all, within the plant room environment itself, the overall plant noise - including pumps and large boilers etc - usually makes more noise than the CHP engine, making additional attenuation for breakout noise unnecessary.

There is also some confusion where acoustic performance is given without an accurate distance being expressed. For example 65 dB(A) @ 10m is correct, but 65 dB(A) is not.

Finally, the common unit of measurement [dB(A)] does not tell the whole story. In layman's terms, the 'A' weighting of this decibel limit adjusts certain frequencies relative to the loudness of sounds within the range of human hearing, but a proper acoustic design should take into account all frequencies within this spectrum.

The reason for this is some manufacturers have engines possessing a 'dominant tonal' frequency. The implication of this is that certain frequencies 'carry' or become structure borne vibration much more than others.



The common pitfalls in CHP design

Incorrect 'Dump Rad' use

A common myth amongst designers is the installation of heat rejection radiators. These are known in the trade as 'dump rads', because they simply dump heat energy.

The myth is: we want to use the CHP to create electricity even when we have no heat demand on the building, so let's install a dump rad and shed the heat.

There is no economic basis for doing this. Given that CHP produces heat energy as a significant output from the gas fuel used to drive it, dumping this heat energy completely destroys the financial proposition of operating the CHP.

The only time dump rads are essential is if the CHP is being used for standby power purposes. This is because you could have a mains failure at a time when you have no heat load, in which case you would certainly need to dump the heat in order to keep the CHP running to make use of the electricity.



Misunderstood value of exporting power back to the grid

Some designers believe you can size CHP for heat demand in the building and ignore electricity demand, on the assumption that CHP running costs can be covered by surplus generated power being exported out onto the grid and sold. For small scale CHP this may be largely a myth.

Generally, for an electricity company to give you a contract to purchase surplus exported power at a meaningful tariff, they would require a fixed minimum quantity of power always available at certain hours of the day.

As most CHP is installed on a heat led scheme (asked to run when the building has a thermal demand) it is unlikely that you can produce sufficient surplus electricity at a time of day when the electricity company will buy it, and sustain this for the consistent periods of time they may require.

In any case, due to the commercial situation in the energy market, small-scale export power (without FITS) attracts pitifully low costs per kilowatt. This means that the value of export power is unlikely to justify burning the gas and paying maintenance charges to operate the CHP, when unable to also utilise the value of the heat energy.

Excessive return water temperature

The one single factor that mostly ruins CHP schemes is this: return water (the temperature of water coming back **to** the CHP **from** the building) having a temperature above that which is necessary for the engine to be cooled.

Keep in mind that unlike the radiator on your car engine, the CHP engine depends on shedding its heat output into the client building for the heat to be made available, and in return is receiving cooling water back to the engine within parameters. When this condition is not met, the CHP will continually shutdown on over-temperature alarm.

This causes increases in maintenance cost, and significant limitations on the financial return the client gets from his investment.

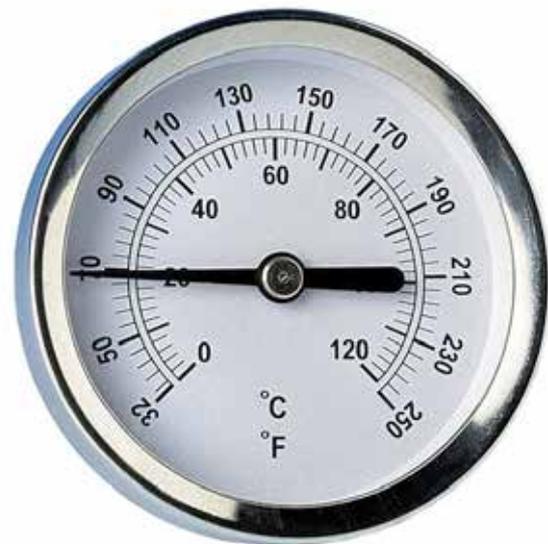
The most common causes of installations where return water temperature is excessive are:

- CHP oversized.
- Poor mechanical design (the arrangement of the pipework and the relationship between the CHP and the boilers).
- Inadequate control (BMS system unable to schedule CHP / boiler plant /and any associated control valves or thermal storage vessels).

“

Keep in mind that unlike the radiator on your car engine, the CHP engine depends on shedding its heat output into the client building for the heat to be made available

”



Oversizing of CHP systems

There seems to be a tendency for CHP to be oversized, especially when the selection is based on thermal output. This leads to reductions in annual running time, and considerable loss of financial saving for the client. In extreme cases, it can lead to physical damage due to excessive shutdowns and failures. Conservative is the principle. When in doubt, undersize.

It can be shown that a smaller machine running for more hours a year, can often provide a better energy output and carbon saving than a larger machine running less frequently.

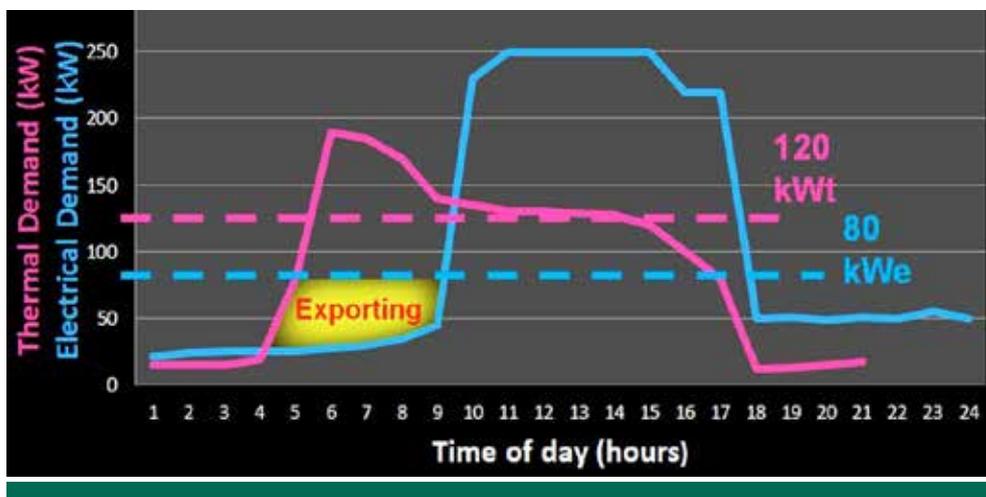
As we look at in the white paper Combined Heat and Power Systems – **When is CHP the right renewable energy choice?**, there are many different drivers behind the use of CHP systems. These tend to influence the sizing decision, often wrongly. For example, several software packages used to select plant for compliance with various regulations (i.e. Part L), tend to take a ‘top-down’ look at CHP size - deciding first the total collective energy requirement for the building, and then seeking to provide a certain percentage of this from the CHP.

This is not the same thing as working out the base load and starting from a ‘bottom-up’ assessment. Practical experience has shown that schemes designed from this method have often produced results post-installation that nowhere near meet the expectations of the original designer. The root cause of this is usually over sizing, leading to excessive return water temperature during low load conditions, leading to premature shutdowns of the plant.

Two sizing approaches are common. Firstly, for a new building energy estimates can be used. Secondly, for an existing building actual energy consumption data should be available and can be input into various cost studies to compare the effect of CHP with the current energy situation.

This is much more reliable as it gives a realistic indication of the current base load of the building. In situations of doubt, or when critical financial targets must be met, there is no substitute for installing electricity and heat metering equipment to obtain energy data measured at source over a period of time.

Issues of spatial arrangement, acoustic cost, and other install considerations can often be improved by designers leaning towards under sizing rather than over sizing.



Use of buffer vessels for CHP systems

In this context, a 'buffer vessel' really means a 'thermal store' - in other words a tank able to accumulate a quantity of pre-treated water, held ready for use. However, for the purposes of this article we will stay with the general industry term of 'buffer vessel'. As a general rule the only time you would have a buffer vessel is if your operating strategy permits the CHP to run during times when the building has a low heat demand. This is then used to 'recharge' the buffer vessel, providing a store of hot water that can be used during the next heat up cycle of the building.

A common myth is that if the CHP may be oversized, increasing the volume of buffer vessel storage is the solution. In practice, after a certain number of heat up and discharge cycles, the buffer vessel is full of hot water and there is no longer any cooling provision to the CHP.

The basic principle is, whatever size your thermal store is, this does not eradicate the basic flaw that if your CHP is producing more heat than the building can use, it is oversized.

Where buffer vessels are correctly employed, they are of considerable benefit as they can extend the running time of the CHP per day thus increasing the savings and profit to the end user.

When they are employed, careful attention must be paid to the mechanical arrangement and the relationship with the BMS for control purposes. The buffer vessel should be kept completely separate from the boiler circuit. There is usually no basis for storing boiler generated hot water in the same vessel as the CHP.

“

A common myth is that if the CHP may be oversized, increasing the volume of buffer vessel storage is the solution

”



Summary

There are many reasons to specify a CHP system (see white paper Combined Heat and Power Systems – When is CHP the right renewable energy choice?) but the design and specification often require consideration of many factors, some of which are commonly overlooked.

The key factor to get right is the suitability of the system before the detailed design process begins.

Once that has been established, the complex design and specification process should begin and take into consideration:

- Design Philosophy
- Operating Strategy
- Relationship With Boilers and BMS
- Electrical Infrastructure
- G59 embedded generator regulations
- Spatial Requirements
- Acoustic Considerations
- The common pitfalls in CHP design

This combination of specification consideration and common errors should leave you in a position to commission the installation of an energy efficient, commercially viable CHP system, that works with the building infrastructure and meets the thermal and electrical requirements of the business.