Unlocking optimum CHP performance in future power systems

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The strong growth in intermittent renewable power is driving change in Europe’s energy market. With intermittent wind and solar power given feed-in priority, in support of global decarbonisation aspirations and national carbon reduction targets, an increasing portion of the thermal fleet must switch from baseload operations to delivering a more flexible and intermittent output that provides power only when lower emission sources are not available.

Despite the considerable challenges brought by the paradigm shift towards renewables, including increased price volatility and reduced running hours, significant opportunities remain for CHP plants. If supported by the right technology, such facilities will not only continue to operate profitably in partnership with renewables, they can also take advantage of additional income generation opportunities.
**CHP in the generation mix**

Generating power and heat via CHP is already desirable in today's energy mix, due to the potential for optimally designed systems to achieve energy efficiency of up to 90%. Indeed, as a result of this high efficiency, CHP is commonly ranked second, behind wind and solar power, in terms of grid feed-in priority.

However, much like the power sector, CHP has been affected by increasing price volatility and by the generation variability of renewable energy. For example, when wind generation peaks, there will be excess power on the market and consequently lower power prices, resulting in reduced opportunities for CHP plants to generate earnings through power markets.

Today, CHP plants typically operate seasonally according to peaks in demand. In winter, when heat is in high demand, CHP plants generate heat while simultaneously generating power as a by-product to be sold to the grid. While in summer, plants cease operation because heat load is typically below the minimum load of the plant, and power prices are lower than in the winter, making operation less economically viable.

**Redefining CHP operating patterns with SPG**

However, this operating pattern is set to change due to the ‘dynamic’ capabilities of Smart Power Generation (SPG), a technology pioneered by Wärtsilä. SPG enables an existing power system (either CHP or power only) to operate at its maximum efficiency, absorbing current and future system load variations and providing dramatic savings. In the context of CHP plants, an SPG application would involve replacing the system's prime mover, typically a combined cycle gas turbine (CCGT), with agile, internal combustion engine (ICE) power plants. The key benefit this SPG capability brings is ultra-fast ramping, which would enable the CHP plant to start in less than one minute and reach full load in less than five minutes. When considered as part of a generation mix increasingly dominated by renewables, this means a CHP plant equipped with SPG could turn on almost instantaneously to provide power in the summer, when profitable, and cease operations when prices are reduced.

**Fast ramp times – an in depth analysis**

Wärtsilä maintains that SPG offers the only feasible route to a reliable and economically viable future power system with a high penetration of renewables. This solution is supported principally by the fast start up times associated with SPG (applicable to a CHP or power only facility), which are demonstrated in Figure 2.

The main benefit of fast ramp-up times is the removal of the costs associated with ‘equivalent operating hours’: the need to operate an engine with a slow ramp-up time for significantly longer than its power is required, to account for start up and shut down times. For example, in a previous system, where power plants generate a steady load, maintenance shutdowns would take place only every 10,000 hours. In a new system with a high integration of renewable energy, this is not possible, as plants are required to ramp up and down on a regular basis to balance wind and solar power. In an anecdotal example, this means that it may take ten hours to start a plant in order for it to operate for five hours, meaning 15 hours are placed on the 'lifetime clock' of the power plant. These hours are further extended if power prices dip within the five-hour operating period, meaning the plant may stop after one hour of operating and then be restarted again after two hours. This would equate to ten hours for the first start, one hour running, ten hours for start two and then another four hours of running. Collectively, this means 25 hours on the lifetime clock of a plant for each five hours of operation. This is an extremely uneconomical way to balance renewables and highlights why an ICE– as well as a CHP, should an owner look to provide renewables balancing in the summer– would be far more advantageous in power applications. With two-minute start times,
SPG eliminates the need for equivalent starting hours, meaning maintenance on the plant is only required for the actual hours that the plant runs.

Another key benefit of SPG is modularity. In the past, utilities picked larger facilities in order to realise economies of scale in terms of efficiencies and cost, but this approach is losing favour. As the requirement to balance renewables increases, so do the instances where the plant is required to operate at partial load, which increases the maintenance burden and results in less power being sold to the market. In contrast, it is possible to ‘decouple’ each turbine in an SPG power plant. For example, in a 200 MW unit, there could be 10 to 20 smaller engines in a row, each capable of performing at high efficiency in isolation. This means the power plant owner can go to the power market and offer, for example, only 10 MW as one ‘slice’ and operate at high efficiency.

Cost-benefit modelling
While the examples above offer a strong case for investing in SPG, investment barriers remain. Namely, the upfront investment in an ICE for a power or CHP plant can be around 10–20% more than a conventional CCGT system. Therefore, the case for investment in SPG relies heavily on demonstrating lifecycle benefits. While the anecdotal benefits mentioned above provide a strong case in support of SPG, Wärtsilä brings added conviction through its latest power market modelling. In a study prepared by Energy Exemplar, Wärtsilä examined the benefits of SPG within the capacity extension plan and 10-year dispatch of the California energy system.

Remarkably, the results showed that SPG could save USD 870 million throughout a 10-year dispatch period from 2013 to 2022. Such savings are achieved when the entire existing fleet of aero gas turbines, and a large portion of industrial gas turbines, are replaced by SPG. With SPG balancing renewables, the fleet of CCGT can remain and operate in its most efficient baseload capacity.

These savings come from a number of areas. First, by portfolio optimisation, in which the zero start costs and high operational ramp rates of SPG allow CCGT to focus on generating a more stable dispatch, thus avoiding costs associated with equivalent operating hours. Secondly, further savings are achieved by increasing overall efficiency of the generation fleet, through the replacement of aero and

Fig. 2 – A comparison of power plant ramp-up times for Smart Power Generation technology versus aero gas turbines, industrial gas turbines, combined cycle gas turbines and coal-fired power plants.
industrial gas turbines, which are less efficient compared to SPG. Thirdly, SPG promotes lower marginal power costs, which reduces the need for costly imports and increases trade from exports. Finally, in terms of capacity, with SPG’s fast start-ups and modular design enabling the replacement of part-loading with precise load following, less overall capacity is needed to balance renewables. An added bonus is reduced CO2 emissions of 1.5%, which is made possible through heightened efficiency.

**SPG in practice**

While some utility professionals remain comfortable with the practice of part-loading to achieve flexibility, due to the widespread use of the technology in traditional power systems, the most forward thinking are already waking up to the benefits of SPG.

Colorado is home to Plains End I & II, the largest natural gas-fuelled ICE power plant in the USA, which delivers 231 MW of power through 34 gas engines from Wärtsilä. The site is located in Colorado, an area with a high proportion of intermittent wind-driven generating capacity, which demands Plains End to cope with sudden load swings. In fact, the plant’s local utility, Xcel Energy, expects Plains End’s grid-balancing capacity to routinely exceed changes of 20 MW per minute, which the plant is able to compensate for by ramping from minimum load to full load and back again in record time.

**Additional opportunities for CHP**

CHP owners may recognise the opportunity that SPG can provide, in terms of bringing their facilities online in the summer to dispatch power when profitable. However, questions still remain regarding how associated heat generated during the process could be used. The solution to this is adding an accumulator that enables more effective and flexible operation. Accumulators perform best in systems with a high penetration of intermittent renewables generation. They enable the plant to run on full power in the summer, when power prices are high, while simultaneously storing heat. The heat is then discharged when lower power prices make operation of the CHP plant unattractive.

SPG characteristics also open up an additional revenue stream for CHP plant owners, who can utilise its fast starting and ramping capabilities on the ancillary services markets. For example, in a period of low heat demand, a 100 MW CHP plant with ICEs can operate with one unit running and nine units at a standstill. These standstill units can be made available to provide fast grid reserve to power markets, where necessary. Together with heat storage, the gas engine power plant can optimize and then also decouple the CHP.

**Transferring theory to working examples**

While CHP plants are already one of the most efficient means of producing heat and power, the power plant portfolio will become increasingly exposed to price volatility in the power markets and to the variable generation created by increasing shares of intermittent renewable power generation. If the same technology continues to be utilised in CHP prime movers, CHP plants lose out in the power markets, if they are not agile enough to respond to peaks and troughs in pricing. However, with the right technology selection, CHP plants can not only remain competitive, they also can continue running year-round, unlocking significant new revenue streams through summer power production and the provision of services to the ancillary services markets. All the while, heat loss can be prevented through the use of heat storages. Power market modelling by Wärtsilä lends support to the investment case for SPG. In order to cement decisions, Wärtsilä is calling on CHP owners to explore how SPG could deliver cost and environmental benefits to their unique facilities. By applying the theoretical market modelling and anecdotal evidence already collected by Wärtsilä to real case examples, the CHP industry will increasingly realise the benefits of SPG.

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**Fig. 3 – A comparison of the savings possible between 2013 and 2022 when the entire existing fleet of aero gas turbines, and a large portion of industrial gas turbines, are replaced by gas-fired internal combustion engines.**

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