The rise of inlet fogging and wet compression

In a market where gas turbine plants are increasingly being required to take a load following role for renewables, fogging and wet compression can play a vital role if they are properly controlled, writes Thomas Mee III

Gas turbines are now being subjected to harsher cooling as well as a far greater number of starts and stops driven by the growing presence of renewables on power grids around the world. In some areas, gas turbines are increasingly required to take a load following role when production from renewables increases or decreases.

Cooling and rapid starts impose heavy stresses on turbomachinery leading to excess maintenance costs and unplanned outages. In essence, some of the cost of renewable energy is being shifted to gas turbines in increased operating and maintenance costs.

However, it is possible to use fogging and wet compression to augment the amount of power available. This can be accomplished in such a way as to lessen the toll exerted by rapid cooling, improve efficiency, and reduce emissions from gas turbine power plants.

Fog basics

Inlet fogging consists of spraying a fog of demineralized water into the gas turbine inlet as with evaporative fogging, the amount of water sprayed is controlled to reach 100 per cent relative humidity or less, at the gas turbine inlet. Cooling the inlet air to a dewpoint of 64°F (18°C) causes the output to increase by about 5 per cent and the heat rate improves by about 10-12 per cent.

Wet compression fogging consists of spraying mist water than can evaporate in the inlet airbox. This ‘water’ is carried into the compressor where it evaporates and gives an interesting effect.

Wet compression increases the mass flow slightly and reduces compressor work, both of which result in an additional power boost. Since wet compression adds to the cost of the process, the flow will produce a power boost of about 5 per cent while heat rate is improved by about 5 per cent.

Wet compression produces about the same power boost whether the ambient humidity is low or high. If there is no upstream evaporative cooler or chilled air, the air will not be fully humidified. In that case, some of the wet compression spray will evaporate before entering the compressor. Consequently, the power boost will be slightly higher on a hot, dry day as opposed to a cool, wet day.

More than one thousand fog systems have been installed on gas turbines around the world. This includes several hundred systems that provide both evaporative cooling and wet compression. Systems designed specifically for wet compression, with water spray rates of 1-3 gpm/ft² of air inlet flow, have been in use for decades.

Some early wet compression systems caused compressor blade erosion as the moisture added produced debris that was too large. Most have since been retrofitted with better nozzles.

Wet compression seems to be gaining popularity. Systems are currently being installed on seven GE 7FA.5B machines in the US, two Alstom STG units in Turkey and four MHI 600-F machines in Mexico.

In a market where gas turbine plants are increasingly being required to take a load following role for renewables, fogging and wet compression can play a vital role if they are properly controlled. This can equate to higher revenue, reduced fuel costs and lower maintenance costs.

Loadshift shift

Coal and nuclear plants have historically been relied upon for baseload grid power. But stringent environmental regulations have led to many of these plants being shut down. With low natural gas prices and improved gas turbine efficiency, combined cycle plants were looked upon as an alternative form of baseload power — and in some regions,
they do indeed perform this function. But increasingly, both combined-cycle and simple-cycle plants are finding a new role: grid balancing and load following to compensate for intermittent renewable generation in parts of the US and Europe. Grid authorities typically prioritize renewable energy.

One consequence of this policy is that natural gas plants are being forced into a new mode of operation. Many combined-cycle plants were designed with base load operation in mind. Simple-cycle plants, on the other hand, were originally conceived as peakers — only turned on when extra power was required on the grid. Peakers might sometime online on short notice in the middle of the night to satisfy heavy demand. But for most of the year, many of these peakers would not see any hours at all.

There are also losses following power plants that make use of gas turbines. Fuel is all between baseload and peaking or perhaps running for a good portion of the day and being turned off or ramped down in the evening.

But there is a new twist in these renewable-balancing and load-following: As renewable output varies annually seasonally and daily, it has to be supported by baseload and baseload-gas turbine plants.

**Case study:**

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One Ivy Energy combined-cycle plant near Reno, Nevada, for example, is in major shift it’s operating profile between 2006 and the present day: it went from high hours and low starts to many starts but for fewer operating hours. Once new cooling and rapid start begins, the plant saw an impact in terms of lower availability. Plant personnel noted the need for more replacement parts, a greater occurrence of metal creep and a higher instance of blade damage. Rolls-Royce’s Taurus went from two in several weeks to three in a month.

OMA have observed this, too. A 660-MW Gas turbine-lookalike staring at a recent user group that is a big difference between a $200,000 unit and a $200,000 unit in terms of fatigue and footwork movement. A drift-based machine will tend to suffer more from low rates fatigue as it said.

**How inlet fogging can help**

Unlike other forms of power augmentation, such as chilled and multidisciplinary evaporative coolers, fog systems have more stages of fog output. Each stage corresponds to a degree of evaporative cooling or a fraction of a percent of wet compression. This makes it possible to control gas turbine output by varying the number of fog stages in operation at any given time.

Fog systems have typically been turned on only when the gas turbine is above baseline. They are usually designed to stage up to maximum cooling. 100 per cent relative humidity of the gas turbine compression inlet whenever they are operated. However, the control system is not ideal given the current operating environment.particularly for gas turbines that are running under Automatic Generation Control (AGC).

If a fog is set to turn on at when baseline is reached and if the fog system then builds up to full cooling that can cause gas turbine output to spike above the power level that is currently needed. This in turn will cause AGC signal to ramp the turbine down, but when the turbine gets below baseline the fog turns off and the turbine has to ramp back up to compensate. With current fog system controls, the only solution is to operate the stages manually or to disable the fog system.

There is a better way to control systems for gas turbines that are on AGC. The fog stages can be controlled to follow the AGC signal or removes fog stages to get the output needed.

Adding and removing fog stages produces a nearly instantaneous change in output power. The fog stages themselves can be made very small as the grid controller would see little or no difference between changing gas turbine fuel flow or a small guide-vane position, and changing fog injection.

This control scheme will improve plant efficiency and reduce cooling stress as fewer gas turbines would need to be operated at any given time. Five 50s operating with 20 per cent power boost would produce the same power as six 50s operating at baseline and one gas turbine would not have to be operated. This would significantly reduce wear and tear on gas turbines operating at a peak with a large amount of intermittent renewable power.

To accomplish load following by varying fog injection would be beneficial to allow fogging at less than baseline. This would ensure fog stages are available when needed. Where peak load is also accommodated by opening fans, the amount of fogging in operation can be adjusted in proportion to the reduction in air mass flow to avoid inordinate oversizes.

Improved condenser load compression fogging is usually thought of as power augmentation systems, but fog system operation of part load fogging because the cost of the water is invested compression is a very small percentage.

Thus gas turbine operation can make significant economic benefit from evaporation fogging and the fog stages themselves can be made very small which can allow faster gas turbines to achieve the same amount of work with less fuel burned and reduced maintenance costs. Fogging at lower base load can save fuel and improve operating reliability. The secret is in the size of the fog stages.