The rise of inlet fogging and wet compression

06/28/2017

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 heavy cycling as well as a far greater number of starts than ever, 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.

Cycling 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 cycling, improve efficiency, and reduce emissions from gas turbine power plants.
Fogging can lessen the toll exerted by rapid cycling  
Credit: Mee Industries

**Fog basics**

Inlet fogging consists of spraying a fog of demineralized water into the gas turbine inlet air. 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 heavy-frame GT by 20°F (11°C) causes the output to increase by about 8 per cent and the heat rate improves by almost 2 per cent.

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

Wet compression increases the mass flow slightly and reduces compressor work, both of which result in an additional power boost. Spraying wet compression water at the rate of 1 per cent of the air-mass flow will produce a power boost of about 8 per cent while heat rate is improved by about 1.5 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 chiller, 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 1-2 per cent of the air mass flow, have been in use for decades.

Some early wet compression systems caused compressor blade erosion as the nozzles used produced droplets that were 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.05 machines in the US, two Alstom GT26 units in Turkey and four MH! 501F 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.

**Baseload 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 shuttered. 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 baseload 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 come online on some days in the mid-afternoon to satisfy heavy demand. But for much of the year, many of these peakers would not see any starts at all.

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

But there is a new kid in town: renewable balancing and load following. As renewable output varies annually, seasonally and day-to-day, it has to be supported by fast-start and fast-ramping gas turbine plants.

Case study

In California, gas turbine-based power is required from late afternoon to early evening. When called, these plants have to produce their power rapidly.

There are areas with somewhat predictable wind and solar output peaks and troughs over the course of the day. In other places, renewable output can suddenly decrease without warning. Despite sophisticated weather models, it can be impossible to predict these changes with more than a few minutes' notice. Gas turbine plants must ramp up and down to meet these shortfalls. That ramping causes thermal stress, which leads to decreased maintenance intervals.

What is emerging, then, is a whole new mode of operation, with gas turbines operating in ways their designers never accounted for. This might entail several starts and stops over the course of the day, or cycling - whereby the plant ramps up to full capacity and then ramps down to partial load many times daily.

In Texas, wind power accounts for nearly 13 per cent of power production. Gas turbines are often required to start and stop twice per day as wind power output fluctuates. In other parts of the world, the growth of renewables is impacting traditional plant functions.

One NV Energy combined-cycle plant near Reno, Nevada, for example, saw a major shift in its operating profile between 2006 and the present day. It went from high hours and low starts to many starts but far fewer operating hours. Once heavy cycling and rapid starts began, 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 incidence of blade damage. Boiler tube failures went from two in several years to three in a month.

OEMs have observed this, too. A GE Gas Turbine rotor specialist stated at a recent user group that there is a big difference between a 5000-start rotor and a 200-start rotor in terms of fatigue and fracture mechanics. A starts-based machine will tend to suffer more from low cycle fatigue, he said.

How inlet fogging can help

Unlike other forms of power augmentation such as chillers and media-type evaporative coolers, fog systems have stages of fog output. Each stage corresponds to a few degrees 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 baseload. They are usually designed to stage up to maximum cooling - 100 per cent relative humidity at the gas turbine compression inlet - whenever they are activated. However, this control scheme is not ideal given the new operating environment, particularly for gas turbines that are running under Automatic Generation Control (AGC).

If a fog system is set to turn on when baseload is reached, and if the fog system then ramps 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 an AGC signal to ramp the
turbine down. But when the turbine gets below baseload, the fog turns off and the turbine has to ramp back up to compensate. With current fog system control logic, the only solution is to operate the stages manually or to disable the fog system.

There is a better way to control fog systems for gas turbines that are on AGC. The fog stages can be integrated with the gas turbine controls so the AGC signal adds or removes fog stages to get the output needed.

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

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

To accomplish load following by varying fog flow, it would be beneficial to allow fogging at less than baseload. This would ensure fog stages are available when needed. Where part load is accomplished by closing IGVs, the amount of fogging in operation can be adjusted, in proportion to the reduction in air mass flow, to avoid inadvertent overspray.

Evaporative and wet compression fogging are usually thought of as power augmentation systems, but fog system operation at part load has advantages. The heat rate is improved when fogging is used when a gas turbine is operating below baseload. A considerable economic benefit can be realized from part load fogging because the cost of the water is trivial compared to the cost of the fuel.

Thus gas turbine operators can realize significant economic benefit from evaporative fogging and wet compression. The power boost obtained can allow fewer gas turbines to do the same amount of work with less fuel burned and reduced maintenance costs. Fogging at below baseload can save fuel and improve operating flexibility. The secret is in how the fog systems are controlled.

Thomas Mee III is chief executive of Mee Industries, a supplier of inlet fogging and wet compression systems. www.meefog.com