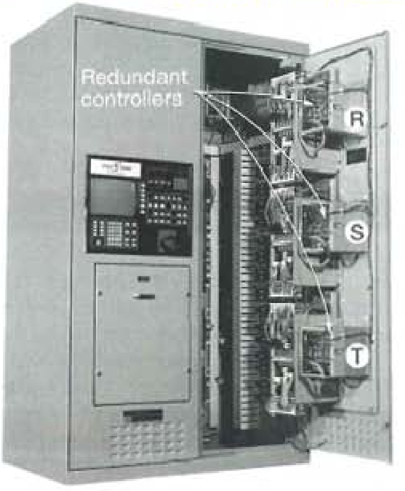
FRAME 6 USERS GROUP

Training: Control, protection systems

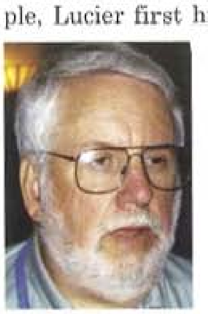
Dave Lucier's (Pond and Lucier LLC, PAL Engineering) one-hour seminar on GE Energy control and protection systems was a valuable introductory course for newcomers to the Frame 6 and a good refresher for others. It began by answering these two questions:



1. Mark IV control panel is characterized by two out of three voting among redundant controllers (R, S, T)

What must be controlled on GE gas turbines? Answer: turbine shaft speed and rate of change of speed (shaft acceleration), exhaust temperature and rate of temperature change, air flow through the main axial-flow compressor.

Five minutes into Lucier's "class" you realize that you're not going to pass this "course" unless you learn GE control terminology. For example, Lucier first hits you with TNH. Not even someone with a PhD in engineering would know what that is. The bottom line: Talking about control systems with a knowledgeable troubleshooter is impossible unless you memorize the "code" this sector of the industry uses to communicate. Lucier says the acronyms are valuable in that they abbreviate the conversation. He calls it the "GE lingo."



Lucier

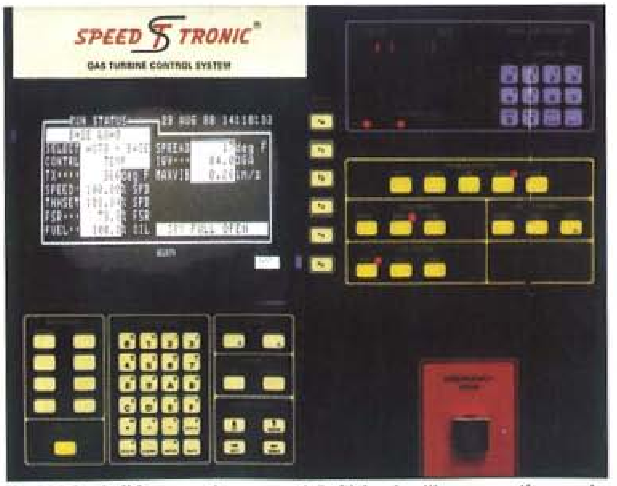
So, for the controlled variables above, TNH is the speed (N) of the high-pressure (H) turbine (T) on two-shaft machines or the speed of the only shaft on single-shaft machines. Units are revolutions per minute (rpm) or percent of rated speed. Acceleration is in rpm/sec or % speed/sec. Percent speed extends from 0% (0 rpm) to 100% (5100 rpm for the Frame 6). Extending the nomenclature to a two-shaft turbine, TNL would be the speed of the low-pressure turbine (not applicable to the Frame 6).

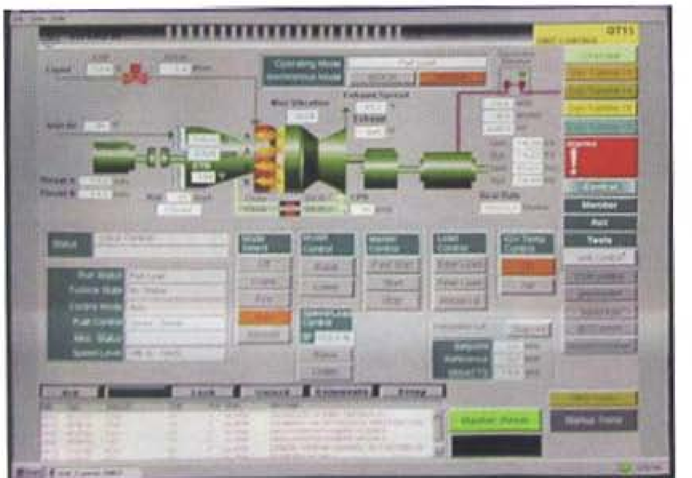
TTX, the average exhaust temperature, is in units of degrees Fahrenheit. The rate of change of exhaust temperature is deg F/sec. GE sometimes uses TTXM; the M stands for arithmetic mean—that is, the average of all active thermocouples in the turbine exhaust.

Air flow is in pounds of air per hour (flow is not actually measured). The variable inlet guide vanes (IGVs) control air flow during startup, operation, and shutdown without actually measuring and displaying the value.

What devices do the controlling? Answer: In liquid-fuel operation, it is a bypass valve (BPV). In gas-fuel operation, there are two valves piped in series: a stop speed/ratio valve (SRV) and a gas control valve (GCV). Finally, the variable IGVs provide the air-flow control necessary to protect the compressor against surge and to maintain the desired exhaust-gas temperature during part-load operation.

Many Frame 6Bs in service, continued Lucier, are equipped with the Mark IV (1982-1989) or Mark V (1989-2000) control systems. Recall

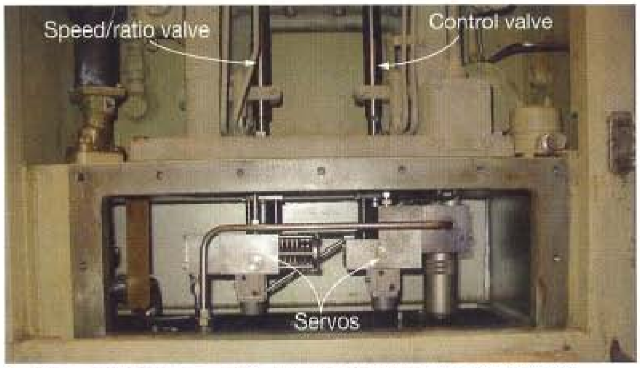




2, 3. Mark IV operator panel (left) looks like an antique alongside a typical Mark V screen available only a few years later (right)

4. Screw-type liquid-fuel pump is driven by the turbine through the accessory gearbox

5. Bypass valve position is adjusted by the Speedtronic™ control panel



6. Flow-divider speed is proportional to fuel flow (left)

7. Stop speed/ratio valve and control valve, and their servo valves, are key components in gaseous fuel systems (above)

that the GE presenter for the controls portion of the OEM session said these systems were good candidates for upgrade/replacement—particularly when applications change or the turbines are moved to new locations.

Lucier flashed a picture of the Mark IV control panel on the screen (Fig 1). The Mark IV was GE's first venture into two-out-of-three voting enabled by triple modular redundancy (TMR) design. Note the R (top), S (middle), and T (bottom) controllers on the door. Comparing the Mark IV operator panel in Fig 2 with the Mark V screen in Fig 3 illustrates how rapidly control systems evolved in only a few years.

Control principles

About half of Lucier's presentation focused on control principles. He began with an overview on the subject, the key point being the OEM's minimum-value-select (MVS) philosophy. In simple terms that means the control sub-system "calling for" the least amount of fuel will be in command. Goal is to produce power with the least amount of energy possible while always being able to protect the turbine by reducing fuel low should an adverse condition arise.

Before digging into liquid-fuel, gas-fuel, and IGV control principles, Lucier explained how the MVS logic worked, discussed TMR circuitry, and reviewed temperature and pressure profile diagrams for base-load operation. The graphs of temperature and pressure were included on a diagram of the engine to give users a visual sense of machine thermodynamics. Also of particular value to the first-timers were GT startup curves that plotted speed, exhaust temperature, IGV angle, and fuel-stroke reference (FSR, the signal representing 0 to 100% of the fuel valve stroke) from the starting of engine auxiliaries through full-speed/no-load (FSNL).

Liquid-fuel control principles. Fuel flow is proportional to bypass valve position and fuel pump speed. In mathematical terms, FFN (flow divider speed) = f (%FSR) × (%TNH). The following are important to note:

- Fuel pump (Fig 4) is driven by the turbine through the accessory gearbox.
- Bypass valve position (Fig 5) is adjusted by the Speedtronic™ control panel. Its job is to subtract fuel flow that you don't want going to the combustor.
- Flow-divider (Fig 6) speed is proportional to fuel flow through the device.

Nomenclature and components identified, Lucier conducted a short clinic to show attendees how to calibrate the liquid-fuel flow rate, running through calculations of flow rate for light-off, FSNL, and base load.

Gas-fuel control principles. Lucier began this portion of the tutorial with a simplified flow diagram that identified the three gas pressures of importance: P1, the supply pressure, measured just ahead of the gas stop speed/ratio valve (SRV); P2, the pressure in the fuel line just ahead of the gas control valve (GCV) and downstream of the SRV (Fig 7); P3, the pressure in the ring manifold serving all combustors, is downstream of the GCV. Important to note is that P2 is the pressure controlled to assure the correct fuel pressure to the GCV. Lucier concluded this lesson, as he did for the liquid-fuel portion, by showing the users how to calibrate the speed/ratio valve.

IGV control principles. As mentioned earlier, the purpose of the IGVs is to control the flow of air entering the compressor. Lucier ran through a couple of control loops to show how the system works and then moved on to protection systems. IGV operation and maintenance, including a "how to" on setting IGV angle, is another presentation in PAL's arsenal.

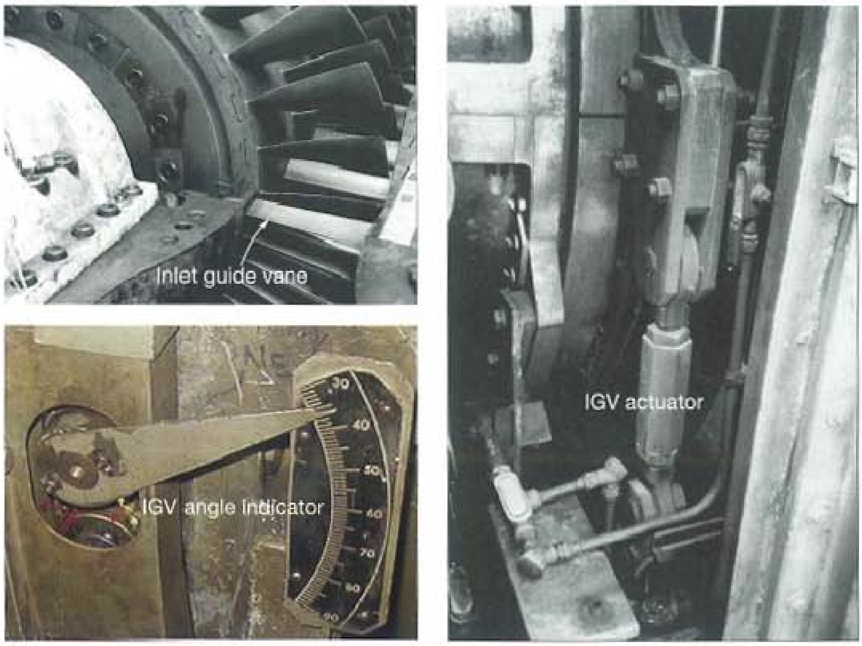
Charlie Pond, Lucier's partner in the firm, recently conducted an IGV clinic at another user-group meeting. Access to that presentation is via the CTOTF's free Internet Bulletin Board Communication Service (http://forums.ctotf.org). After logging on to the bulletin board, scroll to the COMBINED CYCLE Journal Forum for the topic entitled "PAL's Guide to Variable Inlet Guide Vanes." Alternatively, you can access the presentation directly at http://www.ctotf.org/forum/CCJ/3Q2007/VIGVPAL.pdf.

Protection systems. Lucier began by identifying the four primary protections and typical settings. They are:

- Overspeed. Setting on the electronic overspeed generally is 110% TNH; mechanical, 112% TNH.
- High exhaust temperature. Nominal setting is around 1000F.
- Loss of flame.
- Vibration. Limits usually are set at about 1 in./sec and 5 mils peak-to-peak.

Secondary protections include those listed below, and others as required or as requested by the owner/operator:

- Low lube-oil pressure.
- High lube-oil header temperature.



8-10. Inlet guide vanes control the flow of air entering the compressor. IGV angle indicator is shown alongside the vane actuator

- Low hydraulic pressure.
- Generator lock-outs.

Lucier next noted that protection systems are configured as energize to run, de-energize to trip. He then discussed GE's so-called "redundancy by association" concept. What this means is that when operating on liquid fuel and the stop valve closes, the bypass valve opens to enable full recirculation—thereby diverting fuel that would go to the combustors. For gas fuel, when the stop valve closes, the gas control valve also closes immediately. On a unit trip, IGVs immediately move toward the closed position—this to prevent compressor surge.

PAL offers comprehensive O&M seminars on a regular basis. On-demand onsite training also is an option. Visit www.pondlucier.com for details.