TURBINE TIPS
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Subject: Recording and Analyzing Gas Turbine Starting & Operating Data
Applies to: All GE gas turbines, in general, but to those having Speedtronic Mark I & II in particular

A good habit for gas turbine operators to adopt is to carefully record and analyze starting and operating data. They should do this on at least an ***annual*** basis for all gas turbines. That is, to record data, plot variables versus a time base, and analyze the ***signature*** of their gas turbines from initial start signal up to full speed/no load (FSNL). Furthermore, this practice should be continued during synchronizing the generator to the grid, loading to base or peak load, unloading, and shutdown. Yes, even data recorded during the shutdown sequences can be revealing.

Once the operation location is selected (either **AUTO** or **REMOTE**), starting-fuel type selected (typically natural gas or #2 distillate oil), and load level is chosen (**BASE** or **PEAK**), a start signal can be initiated by an operator. Thereafter, the turbine should follow a nearly identical set of functional sequences during an allotted time (typically 7 to 10 minutes, depending upon the model and application). Fig. 1 below shows a remote start is selected and base load level is desired.

Fig. 1: Operation Selector Switch in Remote Start Position at Base Load

Many turbine starting events are either ***speed*** or ***time*** related. For instance, ***firing*** is not permitted until the turbine-compressor rotor reaches minimum speed (20 % or 720 rpm for the frame 7). Once this speed level is achieved, fuel flow starts and sparking is initiated, typically for a one-minute period (2F timer). Later when ***flame*** is detected as a result of cross-firing between chambers, a one-minute up timer (2W) starts. This signals fuel flow to reduce slightly from a “richer” mixture to a safer (warm-up) level. Turbine exhaust temperature is then limited to about 550 ˚F during the cycle. Once thermal soaking is completed, a controlled acceleration is allowed, while continuously monitoring shaft acceleration (rate of speed change, in % per second) and temperature rate (˚F per second).

Fig. 2: Turbine-Compressor Speed Indicator (RPM and Percent)

On older gas turbines (those installed in the 1970s and 1980s), there are over one-hundred relays and contactors; and many timing circuits required for start-up, loading, unloading, and shutdown sequences. As many as fifty circuit boards are also required.

Fig. 3: Typical MS7001B Control Panel with over 100 relays

Most modern gas turbines record operating information automatically and store it in a data base (historian). However, there are hundreds of GE gas turbines that never had automatic data-acquisition equipment installed. In those cases, ***manual*** recording data by plant engineers and operators may be necessary. This requires personnel with clip boards, a stop watch, and time keeper. Coordination is key.

Fig. 4: Dave Lucier instructs operators as to the data he wants recorded

Using a GE MS7001B, Speedtronic™ Mark I as a good example, there are specific parameters (i.e., ***variables***) that should be recorded including (GE symbols noted below):

- ***Time, T,*** in seconds from start signal (record every 15 seconds)
- Turbine shaft speed, ***NHP*** (in RPM or percent)
- Fuel Command Signal, ***VCE*** (in DC volts or Units)
- Average Turbine Exhaust Temperature, ***TXA*** (degrees Fahrenheit)

Also, the following events should be recorded, noting when they occurred (ANSI code symbols given)

- Speed Relays (14HR, 14HM, 14HA, 14HS)
- Sparking (2TV)
- Flame (28FD)
- Alarms, if any

Fig. 5: Average Exhaust Temperature, TXA

Finally, when panel lights go on or off, they should be noted (GE color of lights noted)

- Fuel Limits Control (**BLUE**)
- Acceleration Control (**YELLOW**)
- Speed/Load Control (**GREEN**)
- Exhaust Temperature and Temperature Rate Control (**RED**)
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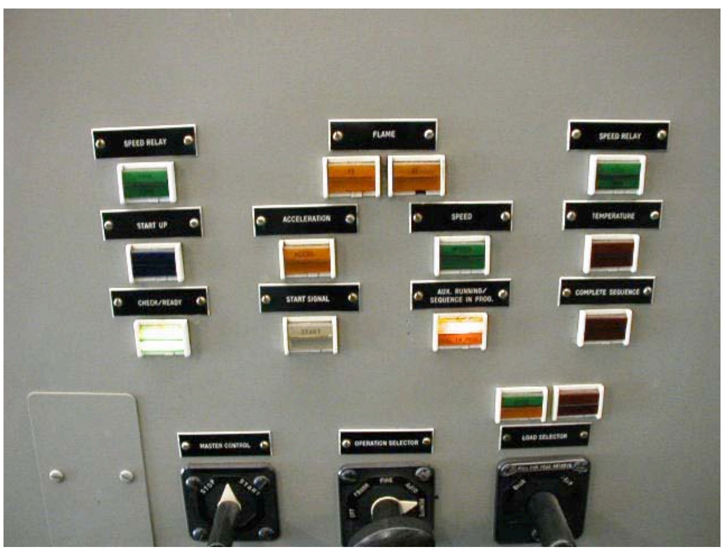

Fig. 6: Panel Lights (speed relays, flame detection, fuel controls)

Data recording takes as many as five people to accomplish. However, it will be time well spent, if accomplished at least on an ***annual*** basis. Also, plotting the data in a consistent manner (similar graph paper and scaling) will allow for revisiting the graphs on occasion and comparing well-running turbines to others that fail to start or operate correctly. Be consistent!

The graphs shown below in Fig. 7 were derived from data collected by plant operators on a frame 7 gas turbine. The data was plotted on graph paper (simplified version depicted herein). The time base is for a 10-minute period. Every minute represents 4 data points (i.e., recorded data ever 15 seconds). Curves were "smoothed out" for clarity. The shapes of the graphs and time duration between events can be very revealing.

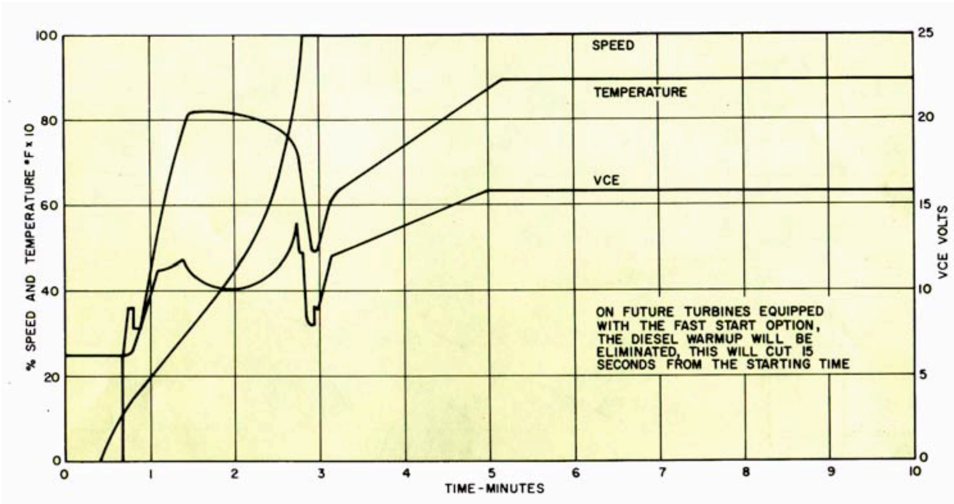

Fig. 7: Starting and loading graphs derived and plotted from data recorded

By studying the data, a plant engineer should be able to determine if the turbine is starting and operating correctly. Experience is a key to analysis. Observation of data peaks, for instance the hottest temperature (810 ˚F in the graph above) was noticed during start-up. It occurred at approximately one minute, 30 seconds after the start signal at time zero. This is when exhaust temperature control (**RED** light) reduced **VCE** level. Also, acceleration control "kicked in" at about 2 minutes, 45 seconds to cut back **VCE** (**YELLOW** light on) before the turbine reached 100-percent operation speed. Good data collection is the key.

The chart below shows typical starting and loading times for GE gas turbines. It should be obvious that there are many design variables including starting means (gas expander turbine, diesel engine, electric motor) and types of turbines. However, the fact remains that turbines have an expected starting, synchronizing, loading, unloading and shutdown plan as designed by the manufacturer.

PACKAGE POWER PLANT STARTING TIMES

MODEL SERIES	TYPE OF START	STARTING DEVICE	DIESEL WARMUP TIME	TURBINE STARTING TIME	TIME TO FULL SPEED NO LOAD	TOTAL TIME TO BASE LOAD
LM2500	Normal	Gas Exp	NA	1.5	1.5	5.5
LM5000	Fast Load	Gas Exp	NA	1.5	1.5	2.0
MS5001P	Normal	Diesel	2	7.17	9.17	13.17
	Fast Load	Diesel	1/2	7.17	7.67	9.67
	Emergency	Big Diesel	1/2	4.0	4.5	5.0
MS6001B	Normal	Diesel	2	10.0	12.0	16.0
	Fast Load	Diesel	1/2	6.67	7.17	9.17
MS7001E(A)	Normal	Motor	N.A.	7.5	7.5	19.5
	Fast Load	Motor	N.A.	7.5	7.5	9.0
MS7001F	Normal	Motor	N.A.	13.5	13.5	25.5
MS9001E	Normal	Motor	N.A.	8.17	8.17	20.17
	Fast Load	Motor	N.A.	8.17	8.17	9.67

Fig. 6: Chart of GE Model Series and Expected Starting and Loading Times

In conclusion, the gas turbine can reveal a great deal about itself during starting, synchronizing, loading to base load, unloading, and shutdown. Many events are ***speed*** related; some are ***time*** related. Recording pertinent operating data and plotting it versus a time base can be extremely useful in troubleshooting. Understanding ***normal*** turbine operation is the key to recognizing ***abnormal*** conditions should they arise. Being able to compare start-up and shutdown curves from years past can be very useful to operators, technicians, and plant engineers.

For more information about starting and operating criteria, contact Dave Lucier of Pond and Lucier, LLC at dave@pondlucier.com or by his cellular phone: 518-330-4801.