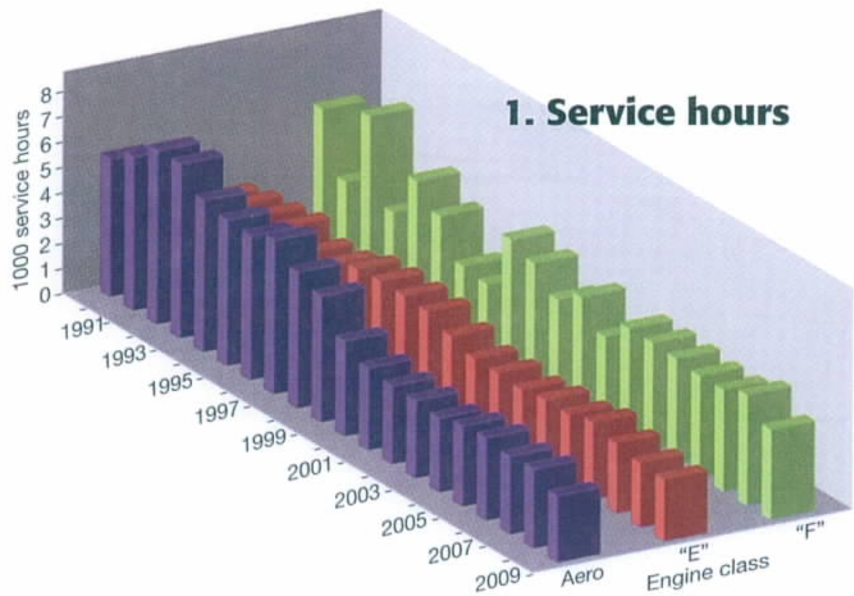
# Changing duty cycles and gas turbine reliability—a look back

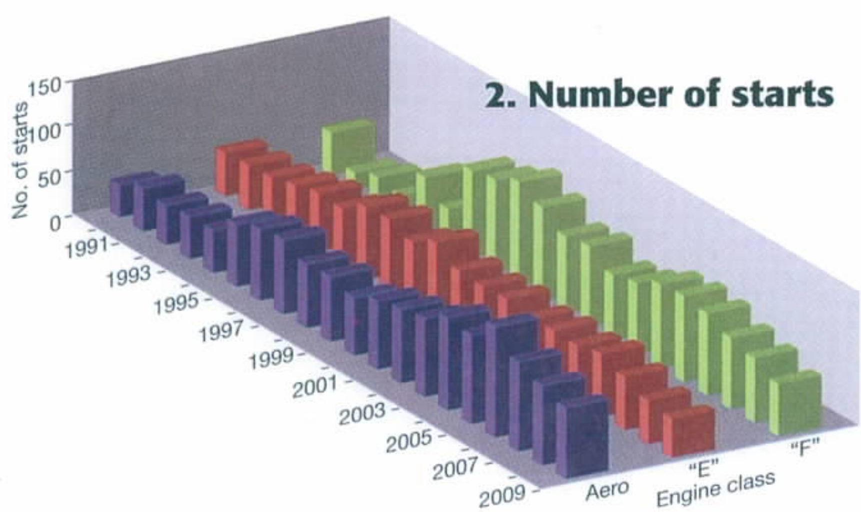
**By Salvatore A DellaVilla Jr,** CEO, Strategic Power Systems Inc

**Characteristics of ORAP data sample for 1991-2010**

| | Aeros | "E" class | "F" class |
|---|---|---|---|
| Average number of units reported | 270 | 230 | 105 |
| Maximum number of units reported | 552 | 290 | 336 |
| Percent of units in combined cycle | 72 | 59 | 87 |
| Percent of units burning only natural gas | 95 | 91 | 99 |




**1. Service hours**




**2. Number of starts**

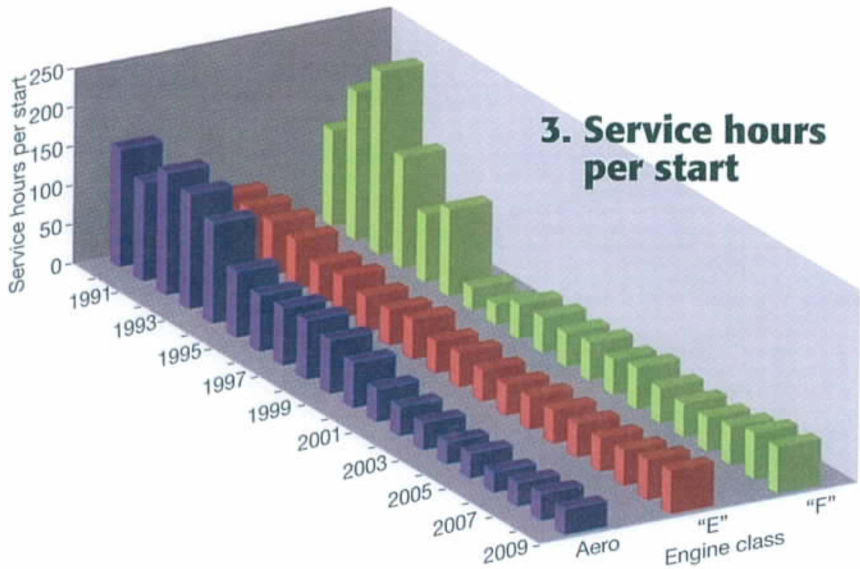
"In June of 1892, a jubilant Charles Scott, the young Westinghouse engineer who had assisted Tesla when he'd first come to Pittsburgh, announced this first commercial use of the whole Tesla system, including the long problematic induction motor, in the *Electrical Engineer.* 'The aggregate time lost. . .was, by actual count, less than 48 hours during three-fourths of a year. . . .'"

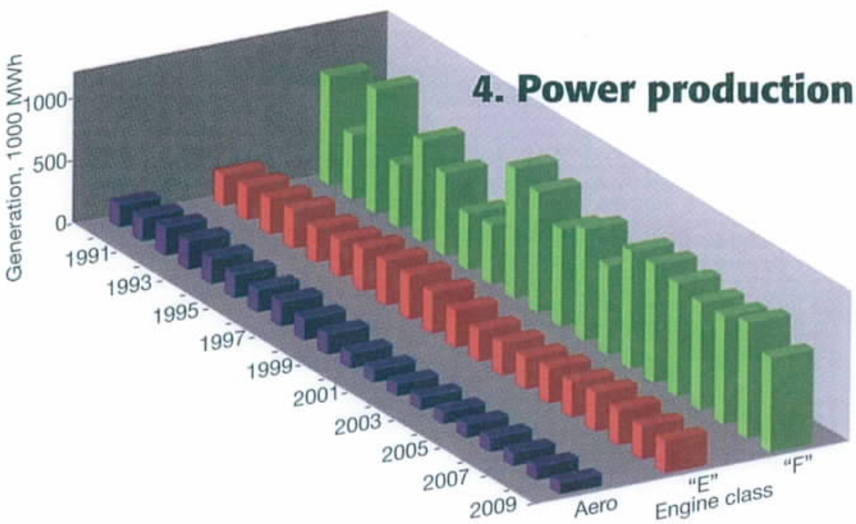
From Jill Jonnes' *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*

Forty-eight outage hours over three-quarters of a year translates to a reliability factor of 99.3%. Thus, from the very start of the electric power industry, the reliability of each product developed—such as the first ac induction motor—was recognized as a key performance indicator required for commercial acceptance and economic viability.

The industry has grown and the technologies it relies on have advanced, but there continues to be a need to understand how powerplant equipment is performing relative to market expectations for high reliability. Changing patterns in demand have resulted in challenging duty cycles that require operating flexibility and this will impact the reliability and capability of plants powered by gas turbines.

For more than 20 years, data from the ORAP® program obtained from numerous operating powerplants worldwide have provided the opportunity to assess and understand trends in equipment duty and performance. The following analysis reviews ORAP data compiled for aero, "E," and "F" class engines in electric generation service to identify operational differences based on equipment size/




output and performance. Two 10-year periods are compared: 1991-2000 and 2001-2010. The data pool is described in the table.

Every performance assessment should begin with snapshot of how the equipment or generating facility was operated during the period under review. Service hours, or the amount of time power was supplied to the grid—that is, the elapsed time from breaker close to breaker open—is a key metric (Fig 1). Service hours also can be characterized by service factor, or the percentage of time the unit is generating power.

In addition, the number of successful starts (Fig 2), the service hours per start (Fig 3), and the power generated (Fig 4) are important considerations necessary for understanding equipment duty cycle or mission profile. Data presented in the illustrations reflect the operation of a typical (or average) unit in the specific technology class (aero, "E," "F").

The following assessment was developed using this information.

**For aeros** during the period 1991-2000 there was a continual year-over-year decrease in service factor, driven by a decrease in service hours. Example: In 1992, the aeros operated just over 6000 hours (85% service factor), with 126 hours per start (48 annual starts); production was 190,900 MWh.

By 2000, annual service hours would gradually, but continually, decrease to just over 4990 hours (70% service factor), and the hours per start would decrease by more than 40% to 70. However, the annual number of starts increased by 50% to 72, while power production dropped by about 12%. This was a clear shift in duty from a typical base-load paradigm to a cycling mission profile.

For the 2001-2010 period, with year 2001 excluded, service hours were more consistent on a year-over-year basis. The service factor was between 40% and 47%, with units operating between 3100 and 3300 hr/yr. Service hours per start declined (to between 25 and 40) as did annual service hours.

The number of annual starts remained high—from 65 up to 122—which is consistent with cycling duty. However, generation declined by more than 40% compared to the previous 10-yr period (1991-2000). Once again, this reflects a clear shift in operating duty.

From a reliability perspective, it is important to note that the number of trips from load have decreased significantly year over year—from a high mark of 10-15 annual trips during the 1991-2000 period to from four to nine for 2001-2010. The time to respond, or to repair also improved significantly.

**"E" class units** had a very consistent mission profile year over year for 1991-2000, as evidenced by the following:

- Annual service hours of 3100 to 3600 and a consistent service factor of about 49%.
- An increasing number of annual starts (from 50 to 86), and a decreasing number of hours per start (from 65 to 41).
- Increased generation—from 245,500 to just over 346,000 MWh on an annual basis.
- Two to three annual trips from load, with a time-to-repair of 30 to 100 hours—a consistently high level of reliability.

From 2001 through 2010, service factor declined and fluctuated slightly, but over time could be seen as relatively consistent in the range of 34% to 41%. Annual service hours fluctuated between 2400 and 3100, while service hours per start increased from 44 to 56.

Power production was fairly consistent throughout the period, ranging from 252,700 to 308,300 MWh annually. The reliability of "E" class machines remained high with only two trips from load on an annual basis and with the time-to-repair dropping to 30 to 60 outage hours.

The bottom line: Over the full 20-yr survey period, the duty cycle of "E" class units has remained relatively consistent across all metrics.

**"F" class.** Fluctuating service hours characterized the years 1991 through 2000. "F" class technology was introduced to the market in this period and the data provide some interesting insights, as follows:

- From 1991 though 1995, (1) service hours fluctuated from a high of 6500 to a low of 3300; (2) hours per start ranged from 233 down to 90; and (3) production averaged over 728,700 MWh.

  During the next five-year period (1996-2000), service hours declined to just over 3870. A substantial change in mission was reflected by the decrease in average service hours per start to just over 50. This metric, together with an increase in annual starts to more than 90, suggest that "F" class engines typically operated in a cyclic duty cycle during the last five years of the 20th century. Interestingly, power production decreased by only 4% during the period.
- From 2001 through 2010, the operation and duty cycle of "F" class turbines can be characterized as "more consistent year over year." Service factor ranged from 50% to 60%, averaging about 55% on an annual basis. Production increased to more than 850,324 MWh annually. These units clearly remained in cyclic duty service with 60 to 90 annual starts and from 44 to 60 service hours per start.
- The reliability performance of "F" class units improved year over year. Annual trips dropped from an average of 18 to just over four during 1991-2000 and to between two and five from 2001 through 2010. The size of "F" class engines contributed a longer time-to-repair (average of 80 outage hours per trip) compared to "E" and aero units.

Clearly, the market expects units that can start faster and more frequently, and stay online for shorter missions across all technology classes. And this holds true for units in combined-cycle applications, as well as simple-cycle.

Customers will demand more challenging missions in the near future, including faster starts and load-following capability—in particular to accommodate "must take" power from intermittent renewables resources (wind and solar). For more on this subject, visit www.integrating-renewables.org. The consequent impacts on component life limits, repair cycles, and maintenance requirement are not fully understood at this time.

**Back to the beginning.** In 1892, Tesla's first commercial 100-hp, single-phase ac induction motor helped to launch an industry with a bent on product improvement and high reliability. The 99.3% reliability achieved on the first try wasn't too bad.

The industry definitely has come a long way since then. As a point of reference, a typical 100-hp, three-phase induction motor specified for powerplant service today has a running reliability of 99.82%.