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Gas-turbine operating metrics in an uncertain energy market

Posted on January 16, 2019 by Team CCJ

Looking ahead to WTUI 2019 in Las Vegas, March 17 – 20

Salvatore A DellaVilla Jr, CEO, Strategic Power Systems® (Sidebar 1), typically begins preparing for the annual meeting of the Western Turbine Users Inc (this year, March 17 – 20 at the South Point Hotel and Spa in Las Vegas) during holiday quiet time when he can reflect in solitude on the highlights of the year winding down and how they might impact the electric-power business in the year ahead.

DellaVilla called CCJ ONsite's offices afterwards to tell the editors that the déjá vu he normally experiences when reflecting on the industry he has served for more than two-score years was replaced this year with a feeling of what the organizational theorist Karl Weick calls vu jádé—the feeling or sense this is something that has never been experienced before.

"The global market that we all live and work in today, he said, is dynamic and very challenging. The global disruption is palpable, whether from the influx and growth of renewables or from the technical and policy changes that influence investment in conventional generating assets. The bottom line: We now work in an 'uncertain market.'

"Our market also has become an industry of headlines," he continued. "In this competitive and uncertain time we are reading and talking about the survival issues of the largest suppliers to the electric-power industry, GE and Siemens. We hear about the massive financial investment Elon Musk has made in batteries, for cars and industry, and the problems he is having.

"We hear about AEP's proposed $4.5-billion Wind Catcher Energy Connection project incorporating 2000 wind turbines and 360-mile transmission line to move renewable energy from the Texas panhandle to Tulsa where the existing grid would be used to distribute the power to customers. Next we learn that what would have been the largest wind project in the US was canceled because utility regulators concluded the project didn't offer sufficient benefits to ratepayers and rejected it.

"All this uncertainty begs the question, 'What is happening in the gas-turbine market?'

"Fundamentally," DellaVilla says, "the question we have to answer is this: 'What role will gas turbines (both heavy-duty frame engines and aeroderivatives) play in this changing market (or set of regional markets) and what will be the fuel of choice or necessity?'

"Perhaps," he added, "we should rephrase the question and ask, 'What are the opportunities for gas turbines as technology and fuel challenges evolve?'"

1. Who is SPS®?

Strategic Power Systems® Inc, Charlotte, NC, is the industry's leading analytics consultancy specializing in the collection, analysis, and dissemination of O&M data for owners and operators of generating plants—in particular those powered by gas turbines. The firm, formed by CEO Sal DellaVilla more than three decades ago, gained recognition quickly because of its work in support of the Western Turbine Users, which began in fall 1990—a few months before the group incorporated.

Recall that Western Turbine serves owner/operators of GE aeroderivative gas turbines, today focusing on the LM2500, LM5000, LM6000, and LMS100. The popularity of the LM2500 and LM5000 grew rapidly as the power block of choice for many of the cogeneration systems installed to take advantage of the Public Utility Regulatory Policies Act, enacted in 1978. Purpa opened up the generation market to non-utility entities as long as their facilities met certain size, fuel, and efficiency criteria. California was fertile territory for cogen systems.

WTUI offered users, some of whom already were meeting at various plants on an ad hoc basis, a formal structure to support the expanding base of operators. The organization's

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leadership understood new users would require operating knowledge and experience, and would share their desire for continuous product improvement.

They also understood the need to establish and follow a uniform process that WTUI, as an organization, could use to track and report the availability and reliability performance of the LM5000 and LM2500 fleets.

The objective was to have unbiased and accurate data to document the performance of gas turbines and other plant equipment. Users wanted data and metrics they could share among themselves, and with GE. These goals were enabled by SPS's Operational Reliability Analysis Program (ORAP®) and use of this data engine was supported by WTUI and GE.

DellaVilla and company went to work and issued their first ORAP report in June 1991, just three months after the incorporated user group's first meeting. It included data from 24 operating plants representing 19 LM2500s and 14 LM5000s and provided an overview of the reliability metrics that the user desired—including component causes of downtime and engine removal rates.

SPS's service to WTUI members and owner/operators of other engines, including today's largest and most sophisticated frames, has grown dramatically over the years in terms of number of participants, extent of equipment coverage, depth of data analysis, and speed of information delivery.

Looking for answers, DellaVilla reviewed data from a variety of sources, including that published in the "BP Statistical Review of World Energy 2018." Summarizing, he said it shows that conventional powerplants continue to play a significant role in meeting the world's base-capacity needs. Renewables have found a place in the market, and while there is recognition of their potential long-term benefit and value, they are intermittent power at this time—not baseload capacity.

Here are some important points DellaVilla gleaned from the BP report:

- Worldwide generating capacity totals about 6300 GW. Nearly 60% of that capability is installed in six countries: China, the US, India, Russia, Japan, and Germany—in that order.
- Over 86% of the primary energy consumed in these six nations comes from fossil fuels—with coal (for electric production) and oil (for transportation) continuing to play a very significant role.

  Unfamiliar with the term "primary energy"? It is defined as an energy form found in nature that has not been subjected to any human-engineered conversion process. Fossil fuels (coal, oil, and gas), biofuels, wind, solar, and nuclear fuels are all primary sources of energy.
- China (60.4%), India (56.3%), Japan (26.4%), and Germany (21.3%) are major users of coal for power generation.
- Russia (52.3%), the US (28.4%), Germany (23.1%), and Japan (22.1%) are major users of natural gas.
- For the top six energy-consuming nations combined, renewables contribute only 3.8% of the electricity produced, with Germany leading at 13.4%.
- France, No. 7 on the list of largest consumers, relies on fossil fuels for 53.5% of its primary energy—mostly oil (33.5%) and natural gas (16.2%). Interesting to note is that 37.9% of France's electricity is produced by nuclear energy, only 4% by renewables.

Setting the BP data aside, DellaVilla focused on the interrelationship between energy and the environment. "We live in a world that values a clean environment," he said, "and using advanced generation technologies—including gas turbines—is important to help us achieve that goal. There is almost a universal acknowledgement that carbon emissions, in the form of CO2, must be contained. This puts us in a place where we have never been before—vu jádé.

"Whether you believe in the need to curtail greenhouse emissions or not," the SPS CEO added, "policy and regulations influence the market, and the market acts through technology selection and 'buy decisions.' Just follow the investment money.

"Yet there is little press or recognition that the 27% reduction in greenhouse-gas emissions in North America has satisfied the desired reduction in CO2 called for by the Paris Agreement on climate change. This positive reduction was accomplished by a shift to natural gas, a reduction in the use of coal, and the growth in renewables. No other geopolitical region can make the same claim.

"Also, it is valuable to know how gas turbines are performing. ORAP® operating data compiled by SPS offers asset reliability and availability numbers for the recent past, and the present, offering perspective for the selection of future generation resources. Plus, it shows us how the installed base (or a segment of it) is operating regionally, and what changes we have experienced over time."

DellaVilla then walked the editors through the ORAP Simple Cycle Plant RAM metrics (Sidebar 2) for various classes of gas turbines—aeroderivatives, E-Class, F-Class, and Advanced-Class. When reviewing this information presented in Tables 1, 5, 6, and 7, keep in mind that "simple-cycle plant," a term typically used in the reporting of reliability statistics, represents the basic gas-turbine plant arrangement, including the following equipment: GT, controls and accessories, generator, and balance-of-plant equipment to support the gas turbine and generator.

The information compiled in Table 1 comes from 621 aero units for 2018, 657 for 2017, and 834 for the 2012-2016 period. Aeros in the sample include engines from GE, MHPS (formerly P&W), and Siemens AGT (formerly Rolls-Royce), and represent units operating worldwide. A regional analysis of aeroderivative data for the US is presented in Table 2.

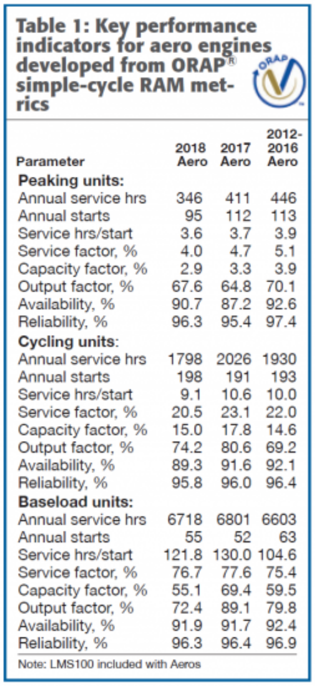


Table 1: Key performance indicators for aero engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 Aero	2017 Aero	2012-2016 Aero
Peaking units:			
Annual service hrs	346	411	446
Annual starts	95	112	113
Service hrs/start	3.6	3.7	3.9
Service factor, %	4.0	4.7	5.1
Capacity factor, %	2.9	3.3	3.9
Output factor, %	67.6	64.8	70.1
Availability, %	90.7	87.2	92.6
Reliability, %	96.3	95.4	97.4
Cycling units:			
Annual service hrs	1798	2026	1930
Annual starts	198	191	193
Service hrs/start	9.1	10.6	10.0
Service factor, %	20.5	23.1	22.0
Capacity factor, %	15.0	17.8	14.6
Output factor, %	74.2	80.6	69.2
Availability, %	89.3	91.6	92.1
Reliability, %	95.8	96.0	96.4
Baseload units:			
Annual service hrs	6718	6801	6603
Annual starts	55	52	63
Service hrs/start	121.8	130.0	104.6
Service factor, %	76.7	77.6	75.4
Capacity factor, %	55.1	69.4	59.5
Output factor, %	72.4	89.1	79.8
Availability, %	91.9	91.7	92.4
Reliability, %	96.3	96.4	96.9

Note: LMS100 included with Aeros

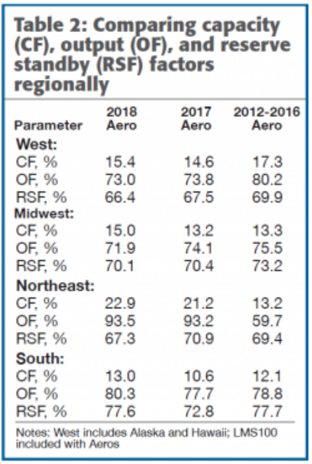
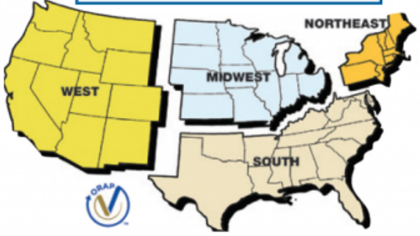


Table 2: Comparing capacity (CF), output (OF), and reserve standby (RSF) factors regionally

Parameter	2018 Aero	2017 Aero	2012-2016 Aero
West:			
CF, %	15.4	14.6	17.3
OF, %	73.0	73.8	80.2
RSF, %	66.4	67.5	69.9
Midwest:			
CF, %	15.0	13.2	13.3
OF, %	71.9	74.1	75.5
RSF, %	70.1	70.4	73.2
Northeast:			
CF, %	22.9	21.2	13.2
OF, %	93.5	93.2	59.7
RSF, %	67.3	70.9	69.4
South:			
CF, %	13.0	10.6	12.1
OF, %	80.3	77.7	78.8
RSF, %	77.6	72.8	77.7

Notes: West includes Alaska and Hawaii; LMS100 included with Aeros



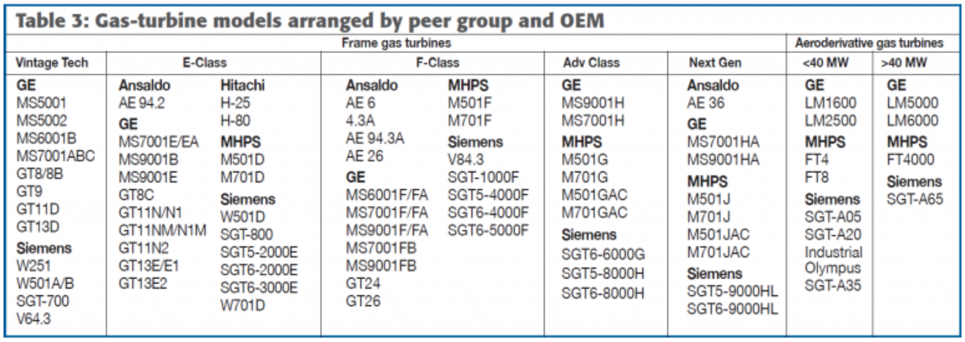


Table 3: Gas-turbine models arranged by peer group and OEM

Frame gas turbines							Aeroderivative gas turbines	
Vintage Tech	E-Class		F-Class		Adv Class	Next Gen	<40 MW	>40 MW
GE MS5001 MS5002 MS6001B MS7001ABC GT8/8B GT9 GT11D GT13D **Siemens** W251 W501A/B SGT-700 V64.3	**Ansaldo** AE 94.2 **GE** MS7001E/EA MS9001B MS9001E GT8C GT11N/N1 GT11NM/N1M GT11N2 GT13E/E1 GT13E2	**Hitachi** H-25 H-80 **MHPS** M501D M701D **Siemens** W501D SGT-800 SGT5-2000E SGT6-2000E SGT6-3000E W701D	**Ansaldo** AE 6 4.3A AE 94.3A AE 26 **GE** MS6001F/FA MS7001F/FA MS9001F/FA MS7001FB MS9001FB GT24 GT26	**MHPS** M501F M701F **Siemens** V84.3 SGT-1000F SGT5-4000F SGT6-4000F SGT6-5000F	**GE** MS9001H MS7001H **MHPS** M501G M701G M501GAC M701GAC **Siemens** SGT6-6000G SGT5-8000H SGT6-8000H	**Ansaldo** AE 36 **GE** MS7001HA MS9001HA **MHPS** M501J M701J M501JAC M701JAC **Siemens** SGT5-9000HL SGT6-9000HL	**GE** LM1600 LM2500 **MHPS** FT4 FT8 **Siemens** SGT-A05 SGT-A20 Industrial Olympus SGT-A35	**GE** LM5000 LM6000 **MHPS** FT4000 **Siemens** SGT-A65

Table 3 is important for clarification purposes. Mergers and acquisitions and renaming of gas-turbine models in the last five years or so might allow misinterpretation of the ORAP data if you have not kept up on industry changes. To illustrate: Engines formerly associated with Alstom now appear with traditional GE and Ansaldo assets.

You also may be unfamiliar with Siemens' current naming convention, particularly after the company's purchase of Rolls-Royce aero engines. Plus, as noted above, what formerly were Pratt & Whitney aero engines are now part of Mitsubishi Hitachi Power Systems' offerings.

Table 4 categorizes gas turbines by firing temperature and pressure ratio to differentiate among Tables 5, 6, and 7 for E-, F-, and Advanced-Class models. Of interest, too, is that SPS engineers are in the process of updating the technology characteristics presented in Table 4 as they evolve over time. Follow these developments in CCJ ONsite.

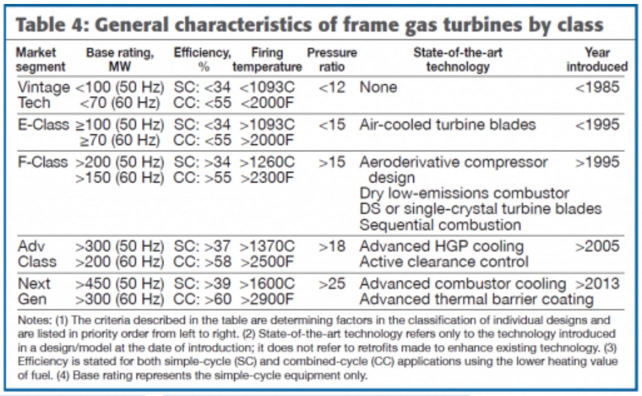


Table 4: General characteristics of frame gas turbines by class

Market segment	Base rating, MW	Efficiency, %	Firing temperature	Pressure ratio	State-of-the-art technology	Year introduced
Vintage Tech	<100 (50 Hz) <70 (60 Hz)	SC: <34 CC: <55	<1093C <2000F	<12	None	<1985
E-Class	≥100 (50 Hz) ≥70 (60 Hz)	SC: <34 CC: <55	>1093C >2000F	<15	Air-cooled turbine blades	<1995
F-Class	>200 (50 Hz) >150 (60 Hz)	SC: >34 CC: >55	>1260C >2300F	>15	Aeroderivative compressor design Dry low-emissions combustor DS or single-crystal turbine blades Sequential combustion	>1995
Adv Class	>300 (50 Hz) >200 (60 Hz)	SC: >37 CC: >58	>1370C >2500F	>18	Advanced HGP cooling Active clearance control	>2005
Next Gen	>450 (50 Hz) >300 (60 Hz)	SC: >39 CC: >60	>1600C >2900F	>25	Advanced combustor cooling Advanced thermal barrier coating	>2013

Notes: (1) The criteria described in the table are determining factors in the classification of individual designs and are listed in priority order from left to right. (2) State-of-the-art technology refers only to the technology introduced in a design/model at the date of introduction; it does not refer to retrofits made to enhance existing technology. (3) Efficiency is stated for both simple-cycle (SC) and combined-cycle (CC) applications using the lower heating value of fuel. (4) Base rating represents the simple-cycle equipment only.

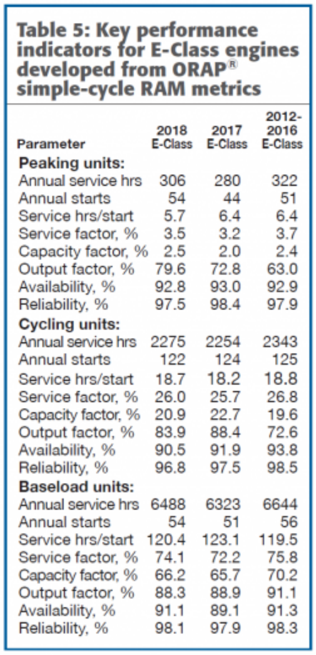


Table 5: Key performance indicators for E-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 E-Class	2017 E-Class	2012-2016 E-Class
Peaking units:			
Annual service hrs	306	280	322
Annual starts	54	44	51
Service hrs/start	5.7	6.4	6.4
Service factor, %	3.5	3.2	3.7
Capacity factor, %	2.5	2.0	2.4
Output factor, %	79.6	72.8	63.0
Availability, %	92.8	93.0	92.9
Reliability, %	97.5	98.4	97.9
Cycling units:			
Annual service hrs	2275	2254	2343
Annual starts	122	124	125
Service hrs/start	18.7	18.2	18.8
Service factor, %	26.0	25.7	26.8
Capacity factor, %	20.9	22.7	19.6
Output factor, %	83.9	88.4	72.6
Availability, %	90.5	91.9	93.8
Reliability, %	96.8	97.5	98.5
Baseload units:			
Annual service hrs	6488	6323	6644
Annual starts	54	51	56
Service hrs/start	120.4	123.1	119.5
Service factor, %	74.1	72.2	75.8
Capacity factor, %	66.2	65.7	70.2
Output factor, %	88.3	88.9	91.1
Availability, %	91.1	89.1	91.3
Reliability, %	98.1	97.9	98.3

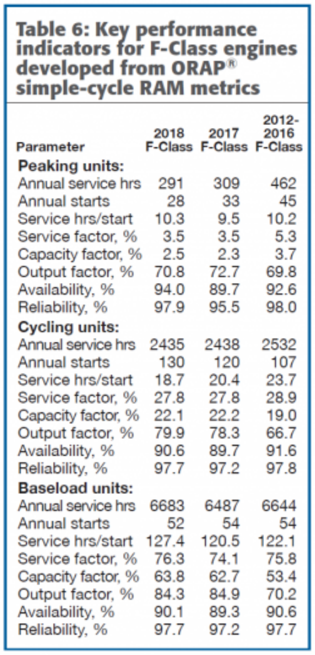


Table 6: Key performance indicators for F-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 F-Class	2017 F-Class	2012-2016 F-Class
Peaking units:			
Annual service hrs	291	309	462
Annual starts	28	33	45
Service hrs/start	10.3	9.5	10.2
Service factor, %	3.5	3.5	5.3
Capacity factor, %	2.5	2.3	3.7
Output factor, %	70.8	72.7	69.8
Availability, %	94.0	89.7	92.6
Reliability, %	97.9	95.5	98.0
Cycling units:			
Annual service hrs	2435	2438	2532
Annual starts	130	120	107
Service hrs/start	18.7	20.4	23.7
Service factor, %	27.8	27.8	28.9
Capacity factor, %	22.1	22.2	19.0
Output factor, %	79.9	78.3	66.7
Availability, %	90.6	89.7	91.6
Reliability, %	97.7	97.2	97.8
Baseload units:			
Annual service hrs	6683	6487	6644
Annual starts	52	54	54
Service hrs/start	127.4	120.5	122.1
Service factor, %	76.3	74.1	75.8
Capacity factor, %	63.8	62.7	53.4
Output factor, %	84.3	84.9	70.2
Availability, %	90.1	89.3	90.6
Reliability, %	97.7	97.2	97.7

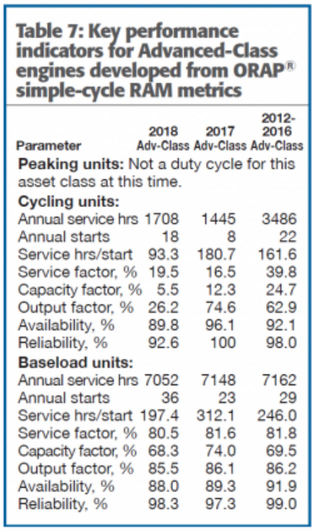


Table 7: Key performance indicators for Advanced-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 Adv-Class	2017 Adv-Class	2012-2016 Adv-Class
Peaking units: Not a duty cycle for this asset class at this time.			
Cycling units:			
Annual service hrs	1708	1445	3486
Annual starts	18	8	22
Service hrs/start	93.3	180.7	161.6
Service factor, %	19.5	16.5	39.8
Capacity factor, %	5.5	12.3	24.7
Output factor, %	26.2	74.6	62.9
Availability, %	89.8	96.1	92.1
Reliability, %	92.6	100	98.0
Baseload units:			
Annual service hrs	7052	7148	7162
Annual starts	36	23	29
Service hrs/start	197.4	312.1	246.0
Service factor, %	80.5	81.6	81.8
Capacity factor, %	68.3	74.0	69.5
Output factor, %	85.5	86.1	86.2
Availability, %	88.0	89.3	91.9
Reliability, %	98.3	97.3	99.0

Information compiled in Table 5 comes from 427 E-Class units for 2018, 473 for 2017, and 470 for the 2012-2016 period. The gas turbines in the sample include engines identified in Table 3 from Ansaldo, GE, MHPS, and Siemens operating worldwide.

Table 6 data come from 549 F-Class units for 2018, 557 for 2017, and 646 for the 2012-2016 period. Again, refer back to Table 3 to identify the specific engines included in the global sample.

Information compiled in Table 7 comes from 25 Advanced-Class units for 2018, 27 for 2017, and 31 for the 2012-2016 period.

DellaVilla concluded the interview with the following observation, "From a review of the data presented, and the operational levels gas turbines are achieving, perhaps there is a bit of déjá vu after all. Natural gas and gas turbines have played a major role in our nation's energy mix for more than two decades—and they will continue to do so for the foreseeable future."

2. Definition of terms

Service hours is the number of hours equipment is in service—that is, generating either electricity or motive force. In-service is generally measured from a commercial perspective, from the time when the equipment is fulfilling its intended service until it is shut down and that service has ceased.

Start. A successful start is achieved when the breaker is closed and synchronized to the grid (power generation) or the driven equipment has reached stable operation (mechanical drive).

Service hours per start is a measure of a piece of equipment's average mission time, or the average number of hours the equipment operates each time it is started.

Service factor is the percentage of time a unit is in service.

Capacity factor is the percentage of maximum possible generation achieved over a given period, using the stated unit capacity.

Output factor is the percentage of megawatt production over a specified time period as a function of the total megawatts that could have been produced had the unit been operated at its nameplate rating for the actual operating hours. This statistic can be calculated in either gross or net terms. Net megawatts accounts for in-plant usage of a portion of the electrical output.

Availability is the percentage of time the equipment is capable of operating.

Reliability is the percentage of time in a given period that the equipment was not forced out of service.

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