GENERATOR SET LOAD FACTOR IMPLICATIONS FOR SPECIFYING ONSITE GENERATORS

One of the important steps in sizing generator sets for any application is to determine the application's average load factor. Understanding this parameter is essential not only for proper power system sizing but also for operability and reliability.

When specifying an engine generator set there are a number of parameters to be identified, and among them is the generator set rating. When choosing a rating, it is important to understand that implicit with it is a value called *Permissible Average Power*, or what is commonly referred to as average load factor. This article will explore how average load factor and generator set ratings are related, and how these parameters come into play when choosing a generator set to meet a particular application.

DEFINING STANDARDS FOR GENERATOR SETS

Most major manufacturers of generator sets use published standards to guide the design and manufacture of their products. Among these standards are those established by the International Organization for Standardization (ISO). Within ISO standard 8528 (particularly part one) we find the definition of four different power rating categories; Continuous, Prime, Emergency Standby, and Limited Time Running. Although ISO-8528 defines all four of these ratings, for the purposes of this article, we will only be discussing the first three as they are the most common.

There are three key attributes which ISO-8528 uses to define each power rating category. They are:

- *Load Profile* – This defines whether the generator serves a constant electrical load, or a variable electrical load.
- *Annual Run Time* – This defines the number of hours the generator is expected to run each year.
- *Permissible Average Power* – This is the average load over any 24-hour period of operation.

So here we see that when a power rating is chosen, along with it comes a predefined permissible average power. We will focus on this average load power. For a complete discussion about power ratings please refer to Understanding Generator Set Ratings.

ISO-8528 defines categories of generator set power output ratings

- *Emergency Standby (ESP) Rating* – The ESP rating is the maximum amount of power that a generator set is capable of delivering, and it is normally used to supply facility power to a variable load in the event of a utility outage. ISO-8528-1 limits the 24-hour average output to 70 percent of the nameplate ESP rating. Figure 3 shows a typical load profile for an ESP-rated generator set.

- *Prime-Rated Power (PRP)* – A prime-rated generator set is available for an unlimited number of hours per year in a variable-load application, as long as the average load factor does not exceed 70 percent of the nameplate rating. The prime power rating for a given generator set is typically 10 percent lower than the standby rating. Figure 4 shows a typical load profile for a PRP-rated generator set.

- *Continuous Power Rating (COP)* – The continuous power rating is used for applications where there is no utility power and the generator set is relied upon for all power needs. Generator sets with this rating are capable of supplying power at a constant 100 percent of rated load for an unlimited number of hours per year. The continuous power rating for a given generator set is typically 25-30 percent lower than the standby rating. Figure 5 shows a typical load profile for a COP-rated generator set.

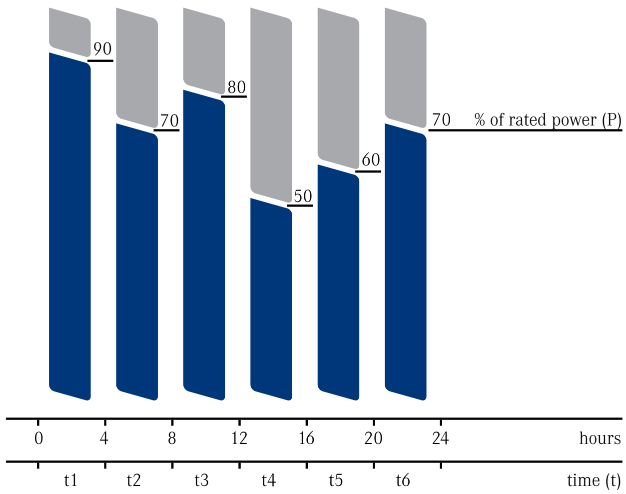
With these definitions, if a manufacturer states that a particular model meets the requirements of ISO-8528, a customer already knows or can easily reference the performance to be expected from that model. However, although ISO-8528 clearly defines each of the power ratings and their associated average load factor, it should be noted that the ISO standard only serves as a starting point for an agreement between a manufacturer and customer. What this means is that manufacturers can (and do) deviate from the standard, but if a manufacturer deviates from the standard, it should be agreed on by both the manufacturer and customer.

When it comes to average load factor, there are two common deviations that some manufacturers make. While the ISO standard allows for a 70 percent average load factor in ESP and PRP ratings, some manufacturers allow for higher values, even as high as 85 percent. The second is an allowance for a 10 percent overload capability for generator sets with a prime power rating. A little later in our discussion we will come back to how all of these numbers can affect generator sizing, but first we should clearly define average load factor, and how it can be calculated.

AVERAGE LOAD FACTOR

The average load factor of a power system is determined by evaluating the amount of load and the corresponding amount of time the generator set is operating at that load. In the case of a power system supplying a constant load this calculation can be done simply by dividing the power supplied by the generator set rating. In most cases however, the loads are variable, so the calculation must be broken into time segments as shown in Figure 1.

FIGURE 1. AVERAGE LOAD FACTOR



$$ALF = \frac{(P_1 \times t_1)+(P_2 \times t_2)+(P_3 \times t_3)+(P_4 \times t_4)+(P_5 \times t_5)+(P_6 \times t_6)}{t_1 + t_2 + t_3 + t_4 + t_5 + t_6}$$

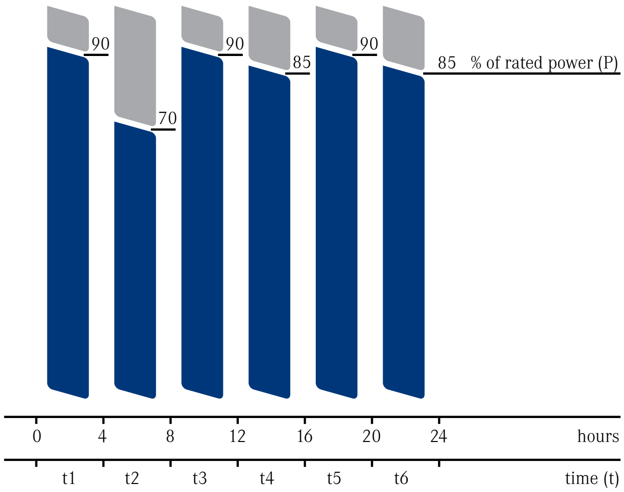
$$ALF = \frac{(90 \times 4)+(70 \times 4)+(80 \times 4)+(50 \times 4)+(60 \times 4)+(70 \times 4)}{4 + 4 + 4 + 4 + 4 + 4}$$

$$ALF = \frac{360 + 280 + 320 + 200 + 240 + 280}{24} = \frac{1680}{24} = 70\%$$

In Figure 1, the 24-hour average load factor is derived from the formula shown under the graph, where P is power in kW and t is time. You can see that although the generator set is loaded to 90 percent of its standby rating for a portion of the time, the average load factor over the 24 hour time span is only 70 percent. This is due to the natural variability of the building load found in many applications where standby generators are installed. Overnight, loads are light because lights are turned off, and much of the equipment is not running. Then, during the morning and throughout the day the loads increase as lights are turned on, equipment is put into use, and things like air conditioners are running more often. For many application, this variation of load is enough to ensure that average load factor limits are not exceeded, but it should be looked at for each new installation. Consideration should also be given to future expansion, and how the load factor may change over time.

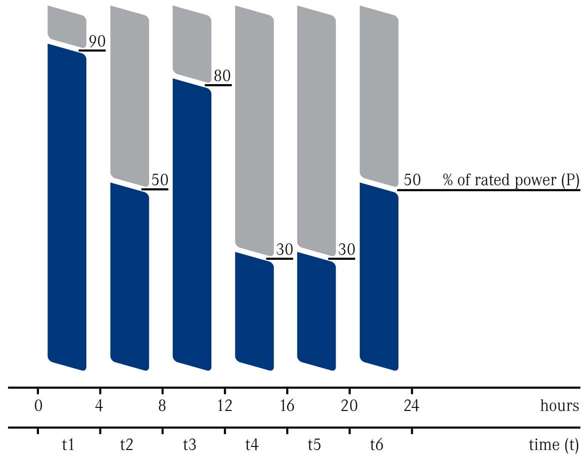
Note also that the calculation for average load factor is done using a minimum of 30 percent load, so even when loaded under this value, 30 percent is used in the calculation. And finally, only operating hours are used in the calculation, any time that the generator set is offline does not count towards the 24-hour average load factor.

FIGURE 2. MISSION-CRITICAL LOAD PROFILE



Average Load Factor = 85%

FIGURE 3. TYPICAL ESP LOAD PROFILE



$$ALF = \frac{360 + 200 + 320 + 120 + 120 + 200}{24}$$

$$ALF = \frac{1320}{24} = 55.00\%$$

HIGH MISSION-CRITICAL LOAD FACTORS

For most facilities with properly designed emergency standby power systems, the possibility of exceeding a power system's 24-hour average load factor limitation is remote. This is because most commercial facilities have variable load profiles that reduce the likelihood a power system's 24-hour average load factor limitation will be exceeded, even during an extended outage. Many facilities also have noncritical loads that can be taken offline during extended outages to reduce the average load factor on the standby system, if necessary.

However, many mission-critical facilities have large, less varying loads that if not properly considered can exceed the published load factor of standby power systems. Two examples of mission-critical facilities with high load factors are data centers and semiconductor manufacturing. In data centers, the computer servers and HVAC equipment create high electrical loads that can vary little over time. Similarly, very high load factors are found in semiconductor foundries, where electric furnaces cannot be shut down without destroying large amounts of product.

As a result of these large, steady electrical loads, the load profile in a mission-critical application is likely to have less variability, in turn putting a more constant demand on the standby power system. Less load variability results in a higher average load factor that will require either specifying a system with larger or multiple generator sets or specifying generator sets capable of a higher average load factor.

In Figure 2, you can see that while the generator sets are not loaded to 100 percent of their standby rating at any time, the average load factor during the outage is near 85 percent. In this case, the customer has taken advantage of generator sets capable of an 85 percent load factor which can deliver over 20 percent more power on average than generator sets rated to only 70 percent average load factor.

EFFECTS OF LOAD FACTOR ON POWER SYSTEM DESIGN

Specifying standby generator sets with a higher-than-average load factor capability can sometimes be a benefit in mission-critical applications. System designers may be able to reduce the size or number of generator sets by using units approved for 85 percent average load factor, as opposed to the 70 percent average load factor. For example, to design a standby power system to supply an average load of 11,000 kW at a 70 percent average load factor would require eight 2,000 kW generator sets. At a 70 percent average load factor rating, each generator set would be able to deliver up to a 1,400 kW average, for a total capacity of 11,200 kW.

8 x 2,000 kW x .70 = 11,200 kW

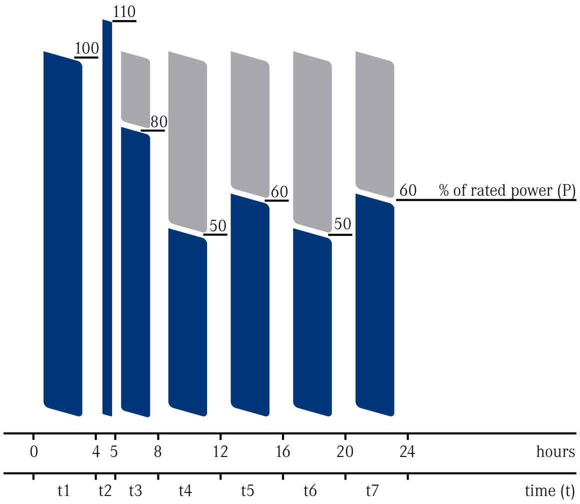
Using generator sets with an 85 percent average load factor capability would require only seven 2,000 kW units. Each generator set would be able to deliver up to a 1,700 kW average, for a total average of 11,900 kW. That amounts to an extra 700 kW of effective generating capacity and a reduction by one in the number of generator sets needed.

7 x 2,000 kW x .85 = 11,900 kW

CONCLUSION

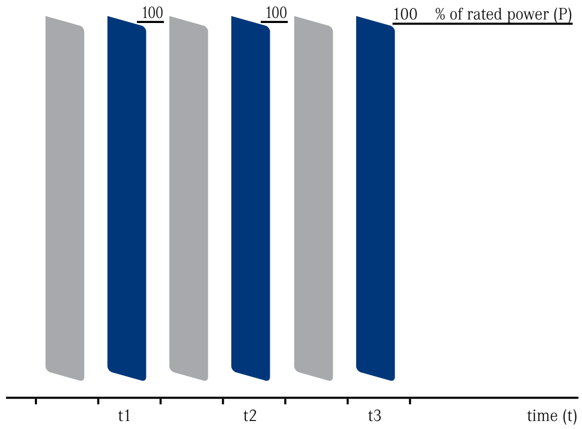
The load factor of any application affects the design and sizing of the standby power system, but for mission-critical applications, particular attention must be paid to load factors because of theses facilities' near constant load and limited ability to reduce their electrical loads. While all major manufacturers of generator sets utilize ISO-8528-1 (which sets the average 24-hour load factor at 70 percent) as their standard, system designers can choose equipment that offers a higher average 24-hour load factor, which may, in turn, result in a system with smaller and/or fewer generator sets. In any case, those specifying standby power systems need to understand average load factor and its implications for business continuity in the face of natural or man-made disasters.

FIGURE 4. TYPICAL PRP LOAD PROFILE



$$\text{ALF} = \frac{1630}{24} = 67.92\%$$

FIGURE 5. TYPICAL COP LOAD PROFILE



Average Load Factor = 100% of COP rating

ISO-8528 sets the 24-hour average load factor for a generator set at 70 percent of the nameplate rating. While some generator set manufacturers allow a higher 24-hour average load factor under certain circumstances, MTU Onsite Energy allows an 85 percent 24-hour load factor on all its standby generator sets (from 230 kW to 3,250 kW).

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MTU Onsite Energy is part of the Rolls-Royce Group. It provides diesel and gas-based power system solutions: from mission-critical to standby power to continuous power, heating and cooling. MTU Onsite Energy power systems are based on diesel engines with up to 3,250 kilowatts power output (kWe) and gas engines up to 2,530 kWe.

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