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Understanding ISO 8528-1 Generator Set Ratings

■ White Paper

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The ISO 8528-1:2013 standard defines various classifications for the application, rating and performance of alternating current (a.c.) generating sets consisting of reciprocating internal combustion (RIC) engines. The classifications put forth in ISO 8528-1:2005 are intended to help align the generator set manufacturer and customer by providing customers a common basis on which to compare generator set ratings from different manufacturers. It is important to note that generator set manufacturers may establish product ratings that go above and beyond the requirements prescribed in the standard.

The ISO standard describes four ratings:

- ESP (Emergency Standby Power)
- PRP (Prime Rated Power)
- LTP (Limited-Time Power)
- COP (Continuous Operating Power)

This paper is intended to clarify the ISO 8528 ratings definitions and provide some examples where the various ratings are applicable. In addition, the paper will address some common misunderstandings that arise when trying to understand ratings.

ESP: Emergency Standby Power

The ESP rating, commonly referred to as the "Standby" rating, is applicable where power is supplied by generator set(s) for the duration of a power interruption by a primary power source or for generator set testing purposes. The ISO 8528-1 standard defines standby power as the maximum power available from the generator set to energize a variable electric load profile, where it has been determined that the total annual runtime doesn't exceed 200 hours of operation. In addition, the average load factor over a 24 hour period shall not exceed 70 percent of ESP unless otherwise approved by the generator set manufacturer (Figure 1).

Then Figure 1 shows how to calculate the average load, P_{pa}. Note that when calculating the average power of a variable load profile, powers which are less than 30 percent of the ESP rating should be considered to be equal to 30 percent and time at which the generator set is at standstill should not be counted.

The ESP rating is only intended for applications where the generator set serves as the backup to the normal utility or primary source. The intent of the rating is not for utility paralleling operation. For applications requiring utility paralleling operation, the prime power or base load rating may be more suitable depending on the expected usage.

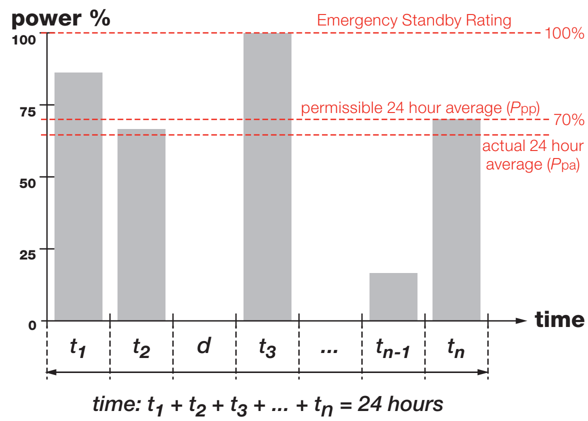
Examples of ESP applications:

- Emergency (such as backup to Life Safety, legally required or critical loads)
- Optional Standby (not required by the Authority Having Jurisdiction, but desired to minimize economic losses or equipment damage at a site due to utility power interruptions).

ESP generator set at a healthcare facility in Salt Lake City, Utah, U.S.A.

FIGURE 1: ESP (EMERGENCY STANDBY POWER)

- For supplying emergency power for the duration of a utility power failure
- Not to exceed 200 hours/year
- Average load factor of 70% of the standby rating over a period of 24 hours
- No negotiated outage operations



Key
t = time
P = power
d = stop
--- Emergency Standby Power (100%)
--- permissible average power during a 24 hour period (P_{pp})
--- actual average power over a 24 hour period (P_{pa})

The actual average power (P_{pa}) is calculated as follows:

$$P_{pa} = \frac{P_1 t_1 + P_2 t_2 + P_3 t_3 + \dots P_n t_n}{t_1 + t_2 + t_3 + \dots + t_n} = \frac{\sum_{i=1}^{n} P_i t_i}{\sum_{i=1}^{n} t_i}$$

where P_1, P_2 ... P_i is the power at time t_1, t_2 ... t_i.

PRP: Prime Rated Power

The PRP rating, commonly referred to as “prime” is applicable when supplying electric power using generator sets in lieu of or in addition to commercially purchased power. ISO 8528-1 defines prime power as the maximum power which a generator set is capable of providing a variable electrical load sequence for an unlimited number of hours per year. In addition, the maximum average load factor over a 24 hour period shall not exceed 70 percent of PRP unless otherwise approved by the generator set manufacturer.

The formula shows how to calculate the average load, P_{pa}. Note that powers less than 30 percent of the PRP rating should be considered equal to 30 percent and the standstill duration should not be counted.

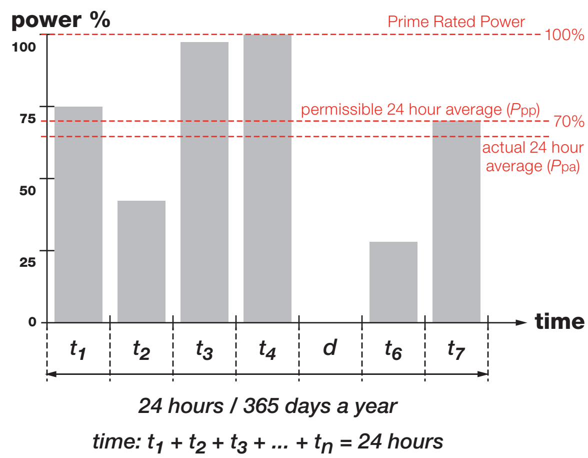
Examples of PRP applications:

- Applications that use on–site generation in lieu of or in addition to a utility electricity supply, typically where utility power is not available.
- Peak shaving and rate curtailment programs

3MVA PRP power station commissioned in an Iraqi oil field camp by a Cummins Power Generation distributor

FIGURE 2: PRP (PRIME RATED POWER)

- ☐ Unlimited number of hours per year (8760 hour/year less service)
- ☐ Variable load
- ☐ Not to exceed 70% average of the prime rating during any operating period of 24 hours
- ☐ 10% overload capability is available in accordance with ISO 3046, AS 2789, DIN 6271 and BS 5514



Key
t = time
P = power
d = stop
––– Prime Rated Power (100%)
––– permissible average power during a 24 hour period (P_{pp})
––– actual average power over a 24 hour period (P_{pa})

The actual average power (P_{pa}) is calculated as follows:

$$P_{pa} = \frac{P_1t_1 + P_2t_2 + P_3t_3 + \dots P_nt_n}{t_1 + t_2 + t_3 + \dots + t_n} = \frac{\sum_{i=1}^{n} P_it_i}{\sum_{i=1}^{n} t_i}$$

where P_1, P_2 ... P_i is the power at time t_1, t_2 ... t_i.

LTP: Limited-Time Power

The ISO 8528-1 standard defines LTP as the maximum power that a generator set is capable of providing for up to 500 operating hours per year under operating conditions and maintenance intervals approved by the generator set manufacturer. The LTP rating is typically applied in constant load applications such as interruptible, load curtailment, peak shaving and other applications that normally involve utility parallel operation and where the yearly generator set run time is predetermined to not exceed 500 hours.

Any application requiring more than 500 hours of operation per year at the Prime Power Rating should use the COP rating discussed in the next section.

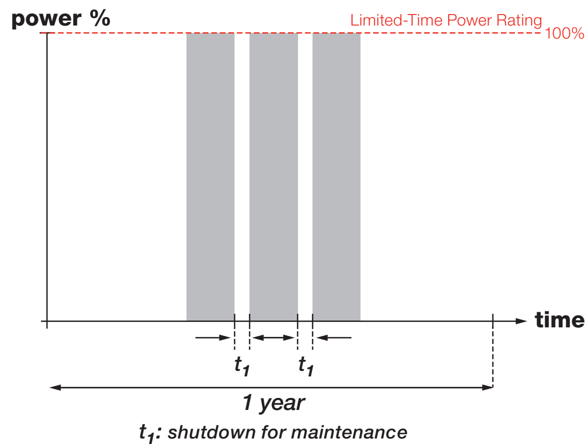
Examples of LTP applications:

- Base loading power stations
  (constant load, less than 500 hours run time per year)

50 MW power plant featuring 30 Cummins QSK60 diesel generator sets located in South Australia to help support the Australian power grid during times of high peak demand or power emergencies.

FIGURE 3: LTP (LIMITED-TIME POWER)

- ☐ Limited number of hours per year (500 hour/year)
- ☐ Non-Variable Load
- ☐ Applications not to exceed 100% of the prime power rating
- ☐ Any operation exceeding 500 hours per year should use the Continuous Power Rating



Key
t = time
P = power
--- Limited-Time Power running (100%)

COP Application: A pair of 1,750 kWe Cummins C1750 N6C generators at a wastewater treatment cogeneration plant near Columbus, Georgia, U.S.A.

COP: Continuous Operating Power

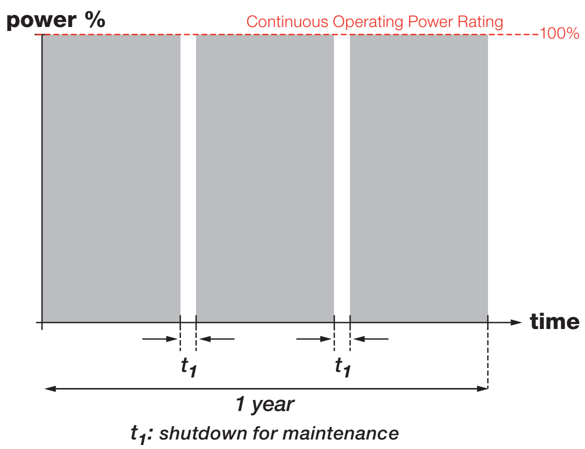
The ISO 8528-1 standard defines COP rating as the maximum power which a generator set is capable of providing at constant power for an unlimited number of hours per year under operating conditions and maintenance intervals approved by the generator set manufacturer. This rating commonly referred to as the "Continuous" rating.

Examples of COP applications:

- Base loading
  (constant load, unlimited annual runtime)
- CHP: Combined heat and power

FIGURE 4: COP (CONTINUOUS OPERATING POWER)

- ☐ COP 8760 hours per year less service
- ☐ Applicable for supplying utility power at a constant 100% load for an unlimited number of hours per year



Key
t = time
P = power
--- Continuous Operating Power (100%)

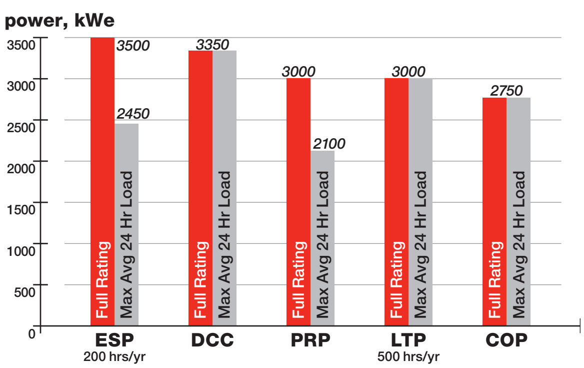
Generator Set Rating Example

Figure 5 shows the multiple ratings offered on a Cummins diesel generator set model C3500 D6E. All the rating shown are based on a lagging power factor of 0.8 per the ISO standard. This generator set model is built with a diesel engine with a total displacement of 95 liters. This example is shown to illustrate the fact that the same generator set model may be offered with multiple ratings. Or, conversely stated, generator sets with different ratings don't necessarily mean different machines.

Note that there is an inverse relationship between the generator set rating and allowable generator set runtime. The higher the rating, the lower the number of hours the generator set is allowed to run in a year. This is due to an inverse relationship between engine life and the engine load. Simply stated, the harder you run the engine, the shorter the engine life (mean time between overhaul – MTBO) is going to be. Therefore, a higher average engine load resulting from a higher rated generator rating is compensated by limiting the number of hours the generator set can run over a given year.

Out of the five ratings shown in the graph, all except the DCC (Data Center Continuous) are based on the standard ISO 8258 generator set ratings definition.

FIGURE 5: GENSET NAMEPLATE RATING



Cummins generator set model C3500D6E – 95L diesel engine platform

Data Center Continuous Rating (DCC)

Some generator set manufacturers offer ratings that exceed the requirements set forth by ISO8528-1 rating definitions. For example, Cummins has developed a power output ratings category for data center applications. The DCC is defined as the maximum power which the generator is capable of delivering continuously to a constant or varying electrical load for unlimited hours in a data center application. Basically, the DCC rating is a PRP rating but without the 24 hour 70 percent average load restriction. The DCC ratings greatly simplify the engineering design process and make it easier for customers to achieve site certification from the Uptime Institute. More information on this rating can be found in the following white paper: Data Center Continuous (DCC) Ratings: A Comparison of DCC Ratings, ISO Definitions and Uptime Requirements. http://power.cummins.com/sites/default/files/literature/technicalpapers/GLPT-5618-EN.pdf

Generator Set Ratings and Overload Capability

The ISO 8528-1 standard doesn't specifically call out overload capability requirements on any of the generator set ratings it defines. However, the industry often expects a 10 percent overload capability for generator sets in applications requiring unlimited time prime (PRP) operation. Hence, some manufacturers allow a 10 percent overload on prime-rated generator sets during emergencies. Operating at 110 percent is restricted to a period of 1 hour within a 12 hour period of operation and the total operating time at the 10 percent overload power can't exceed 25 hours per year. This allowance is in accordance to the ISO 3046-1 standard, a performance standard for reciprocating internal combustion engines.

Power Factor and Generator Set Ratings

The ISO8528-1 standard bases generator set ratings at 0.8 (lagging) power factor ratings "unless otherwise stated" by the manufacturer. Three-phase loads tend to have lower steady state power factors, approaching 0.8, therefore, three-phase generator power ratings are taken at a 0.8 power factor. It is more practical to rate single-phase generator sets at unity (1.0) power factor since most single-phase loads operate close to unity power factor. Hence, some generator manufacturers publish single-phase generator set ratings at unity (1.0) power factor.

Some applications may require the generator sets to operate at a leading power factor. Since most generator set manufacturers publish their three-phase generator set ratings at a lagging 0.8 pf these standard ratings may not reflect the capability of the generator to operate at leading power factor. Hence, in such situations, it is important to consult with the generator set manufacturer in order to determine what generator set will be most suited for the application. Generator set manufactures can typically provide a generator reactive capability curve which defines the boundary within which the generator can operate safely.

Generator Set Ratings vs. U.S. EPA Emissions Standards

The U.S Environmental Protection Agency (EPA) emissions standards for generator sets categorize generator sets as either Stationary Emergency, Stationary Non-Emergency or Non-Road Mobile. The emissions requirements for Stationary Emergency generator sets are less stringent than for the other two categories. Stationary generator sets installed to run only during a utility outage are designated as Stationary Emergency. Stationary Non-Emergency generators are used as both standby power generators and for participation in any electrical utility program that brings a financial gain to the facility owner. An example would be a rate curtailment agreement between the utility and the generator set owner, or in applications where the generator sets are the primary reliable source of power. Codes and details can be found on the EPA website: https://www.epa.gov/stationary-engines.

The ISO 8528-1 generator set ratings are sometimes incorrectly associated with U.S EPA Emissions designations. The emissions category is determined by actual product use and engine horsepower and not electrical rating of the generator set. For example, a generator set with a prime power electrical rating may be designated as EPA Stationary Emergency provided it is being used only for backup power and meets the federally-mandated maximum generator runtime requirements. Most of the time, however, a Standby rated generator set would be more suited for a stationary emergency application and a Prime or Continuous rating would be more suited for a stationary non-emergency application.

More information about emissions regulations is covered in the following white paper: Understanding EPA NSPS emissions regulations for stationary spark ignited engines. http://power.cummins.com/sites/default/files/literature/technicalpapers/PT-8003-EPA-NSPS-en.pdf

U.S. EPA ENGINE DESIGNATION — STATIONARY:

- ☐ Stationary Emergency
  (40 CFR Part 60 Subpart JJJJ)
- ☐ Stationary Non-Emergency
  (40 CFR Part 60 Subpart IIII)

U.S. EPA ENGINE DESIGNATION — NON-ROAD:

- ☐ No emergency distinction for Non-Road
  - ☐ CI (40 CFR Part 89)
  - ☐ SI (40 CFR Part 1048)

Generator Set Ratings vs. the NFPA70 National Electric Code

In the U.S, the NFPA70 National Electric Code (NEC) is often adopted by municipalities as the local electrical code. The NEC has four categories that apply to generator power sources: Emergency, Legally Required Standby, Optional Standby, and Critical Operations Power Systems. Article 700 in the NEC classifies emergency systems as "those systems legally required and classified as emergency by municipal, state, federal or other applicable codes, or by any governmental agency having jurisdiction.

The ISO 8528-1 generator set ratings are often incorrectly associated with the NEC categories but it is important to keep them separate. The fact is, any ISO 8528-1 generator set rating may be used in Emergency, Legally Required Standby, and Optional Standby systems. For example, consider an application with a generator set at a remote facility with no access to a utility source of power and variable load profile. The site power distribution system may comprise of a mix of emergency, legally required standby, and optional standby circuits as defined by the NEC. This application would be an excellent candidate for an unlimited time prime rating.

About the author

Munir Kaderbhai has been with Cummins Power Systems since 2010 as an application engineer. His primary focus is assisting clients and distributors with technical guidance on application-specific issues concerning standard commercial products and unique projects. In addition, he also supports the design and analysis of hybrid power generation systems integrated for telecom and micro-grid applications. Kaderbhai is actively engaged in the Cummins Power Systems' Power Seminar program as an instructor in technical seminars and webinars, and he also provides technical training content to support distribution teams in the North American market.

Conclusion

There are many factors that must be carefully considered when determining the appropriate generator set rating, including the hourly runtime requirements, the load profile, and the generator set's intended application. Special attention needs to be paid to the generator set hourly runtime requirements, the load profile and the type of application the generator set will be utilized in. Operating a generator set in a manner that violates the usage terms for the purchased rating stipulated by the generator set manufacturer may result in a less reliable system. It may also have ramifications on whether or not a manufacturer will honor the terms of a service contract and/or product warranties in case something goes wrong. To determine the correct rating for the generator set, consult with an authorized generator set manufacturer's representative.

For additional information about generator sets, visit power.cummins.com.

References

- ISO 8528-1:2005 Reciprocating internal combustion engine driven alternating current generating sets – Part 1: Application, ratings and performance
- Reciprocating Internal Combustion Engines – Performance – Part 1: Declarations of Power, Fuel and Lubricating Oil Consumptions, and Test Methods – Additional Requirements for Engines for General Use – Fifth Edition
- NFPA 70® National Electrical Code® 2014 Edition
- Title 40, Code of Federal Regulations (40 CFR), 2016
- Cummins Power Systems T-030 Liquid Cooled Generator Set Application Manual, Issue 9, 2015

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