SEISMIC AND WIND LOADING STANDARDS FOR EMERGENCY STANDBY POWER SYSTEMS

Understanding provisions in the latest edition of the International Building Code is critical for specifying emergency standby power systems that will continue to operate after events such as an earthquake or a hurricane.

The International Building Code (IBC) is a comprehensive set of building standards that was first proposed in 1997 by the International Code Council (ICC) and adopted in 2000. The IBC sought to harmonize the many national, state and local codes that govern the design of structures to eliminate duplicative or conflicting standards and, therefore, make compliance more uniform.

By
Benjamin Stratton
Sr. IBC Expert
MTU Onsite Energy
Mankato, MN

The IBC is updated on a three-year cycle the latest version is IBC-2015. Currently, all 50 states and the District of Columbia have adopted previous versions as their de facto building code.

While the main focus of the IBC is structural integrity and fire prevention, certain provisions govern the certification and installation of emergency standby power systems used in locations that are seismically active or subject to high wind loading of up to 200 mph. Depending on the classification of the structure and type of occupancy, seismically certified emergency standby power systems are required to ensure power after a catastrophic event, such as an earthquake or hurricane.

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The primary need for electrical power after such an event is for various life-safety systems that support building egress. These include emergency lighting, elevators, ventilating systems, communication systems, facilities that are classified as Risk Category IV in *Table 1*:

- **Hospitals with surgical or emergency treatment facilities**
- **Fire, rescue, ambulance and police stations**
- **Designated public storm shelters**
- **Emergency response centers**
- **Power-generating stations and public utilities**
- **Structures with toxic or hazardous substances**
- **Aviation control towers and air traffic control centers**
- **Facilities involved in critical national defense functions**
- **Water storage facilities required for fire suppression**

DECIDING WHEN TO SPECIFY A SEISMIC POWER SYSTEM

Not every area of the U.S. or type of structure is required to have a seismically certified emergency power system. According to the IBC, a seismically certified emergency power system is only required in locations and structures that meet certain criteria. *Figure 1* shows the areas in the country that are seismically active and where seismic design must be considered. The criteria includes: importance factor (I_p), building risk category, site soil class and spectral response acceleration.

RISK CATEGORY	RISK CATEGORY OF BUILDINGS AND OTHER STRUCTURES
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities
II	Buildings and other structures except those listed in Risk Categories I, III and IV
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300 • Buildings and other structures containing elementary school or day-care facilities with an occupant load greater than 250 • Buildings and other structures containing adult education facilities, such as colleges and universities, with an occupant load greater than 500 • Group 1-2 occupancies with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities • Group 1-3 occupancies • Any other occupancy with an occupant load greater than 5,000 • Power-generating stations, water treatment facilities for potable water, wastewater treatment facilities and other public utility facilities not included in Risk Category IV • Buildings and other structures not included in Risk Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released
IV	Buildings and other structures designed as essential facilities, including but not limited to: • Group 1-2 occupants having surgery or emergency treatment facilities • Fire, rescue, ambulance and police stations, and emergency vehicle garages • Designated earthquake, hurricane or other emergency shelters • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response • Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures • Structures containing highly toxic materials as defined by Section 307 where quantity of the material exceeds the maximum allowable quantities of Table 307.1 (2) • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions • Water storage facilities and pump structures required to maintain water pressure for fire suppression

Table 1. Structures are categorized based on their function and occupancy in accordance with this table. Risk Categories III and IV always need to be considered for seismic design in seismic zones.

// *Importance Factor* – The IBC uses an importance factor (I_p) to designate whether an emergency standby power system is a critical or non-critical application. A non-critical application has an I_p of 1.0, and a critical application has an I_p of 1.5 when any of the following conditions apply:

1. The emergency standby power system is required to operate after an earthquake to supply life-safety systems, such as egress lighting or sprinkler systems.

2. The structure contains hazardous materials.

3. The emergency standby power system is located in a Risk Category IV structure and its failure would prevent continued operation of the facility.

// *Risk Category* – *Table 1* shows the risk categories of buildings and other structures as listed in IBC-2015. Categories I-III do not normally require a seismically certified emergency power system unless they are located in a seismically active area with short-period response acceleration greater than 0.33 g. (See *Table 2*). However, all Category IV structures require such a system when the importance factor is 1.5 (i.e., essential) and S_{DS} is more than 0.167g.

// *Site Classification* – In any seismically active zone, the potential for structural damage is influenced by the soil type. The least structural damage can be expected on solid rock (Site Class-A), while the most structural damage can be expected on loose, liquefiable soils (Site Class-F). (See *Table 3*)

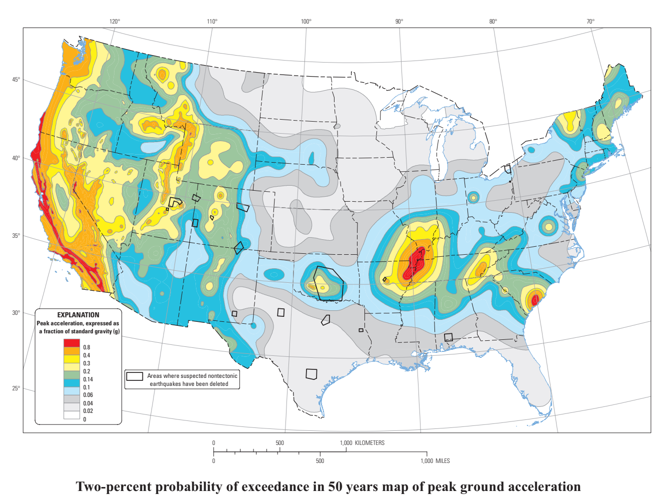


Figure 1. A map of peak ground accelerations (PGA) from the USGS. Areas marked with yellow, red, orange and brown are where seismic design must be considered. (PGA with 2% in 50-year PE. BC rock. 2014 USGS)

SEISMIC DESIGN CATEGORY BASED ON SHORT-PERIOD RESPONSE ACCELERATIONS			
VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g < S_{DS} < 0.33g$	B	B	C
$0.33g < S_{DS} < 0.50g$	C	C	D
$0.50g < S_{DS}$	D	D	D

Table 2. The seismic design category, A to D, is determined by the Occupancy Category and the value of S_{DS} at the building site.

SITE CLASS DEFINITIONS	
SITE CLASS	SOIL PROFILE NAME
A	Hard rock
B	Rock
C	Very dense soil and rock
D	Stiff soil profile
E	Soft soil profile
E	Any profile with more than 10 feet of soil with: 1. Plasticity index > 20 2. Moisture content > 40% 3. Un-drained shear strength < 500 psf
F	Any profile containing soils with: 1. Liquefiable soils; quick and highly sensitive clays; collapsible, weakly cemented soils 2. Peats and/or highly organic clays 3. Very high plasticity clays 4. Very thick soft/medium stiff clays

Table 3. Because soil type greatly affects how structures perform during seismic events, each seismic zone building site needs to be categorized in a Site Class from A to F.

// *Short-Period Response Acceleration* – This is a number (S_{DS}) derived from the expected ground movement forces (measured in g = acceleration due to gravity) in seismically active locations as defined by the United States Geological Survey (USGS) (Refer to *Figure-1*). The higher the number, the more severe the seismic forces acting upon a structure and its contents. This number is used in conjunction with a risk category to determine a seismic design category, A through D.

The following three critical parameters are the basis for determining whether a seismically certified emergency power system is required:

- **An S_{DS} of 0.167g or greater**
- **Risk Category IV**
- **Seismic design category of C, D, E or F**

POWER SYSTEM STRUCTURE MUST ALSO RESIST WIND LOADING

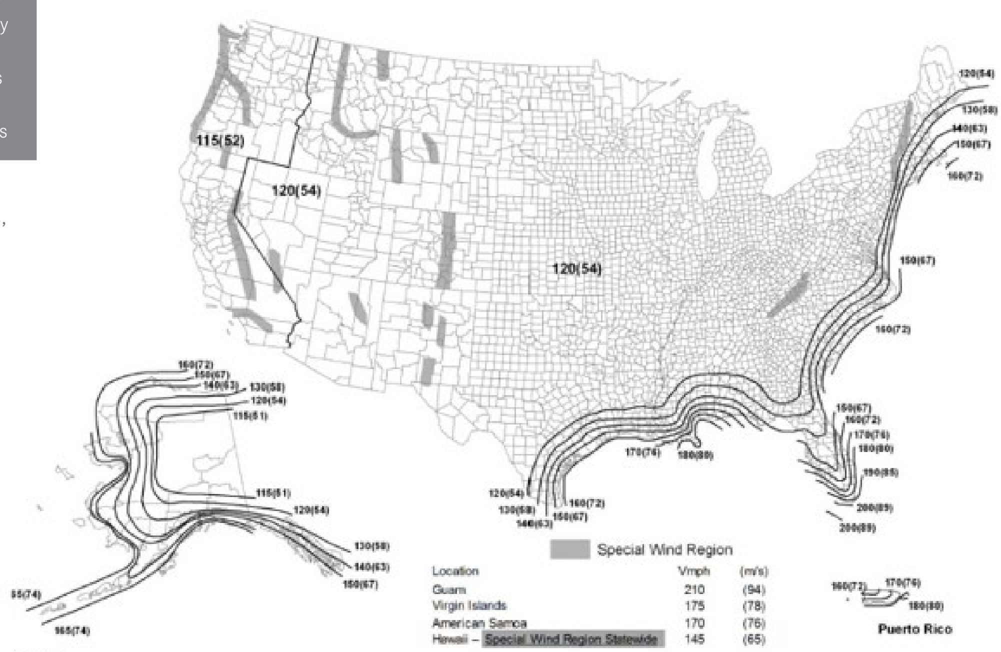
The IBC also addresses wind loading and its effect on the performance of an emergency standby power system. For those states that have adopted IBC-2006 through IBC-2015, the building that houses the emergency standby power system must resist any overturning forces caused by expected high winds and the generator set must stay mounted to its foundation and be operable after the event. *Figure 2* shows the areas of the country where high wind loading needs to be considered in the design of structures that house emergency standby power systems.

SEISMIC DESIGN RESPONSIBILITY

According to the provisions in IBC-2015, the design team is responsible for making sure an emergency standby power system stays online and functional after a seismic or high wind loading event. Teams include: emergency standby power system manufacturers, suppliers, installers, design team managers, architects and consulting engineers. Each has a critical role in making sure that structural and non-structural components perform as designed.

IBC-2015 Section 1704.4 Contractor Responsibility states:

Each contractor [i.e., all members of the design team listed above] responsible for the construction of a main wind- or seismic-force- resisting system, designated seismic system or a wind- or seismic-resisting component...shall submit a written statement of responsibility to the building official and the owner prior to the commencement of work on the system or component. The contractor's statement of responsibility shall contain



Notes:
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1700 Years).

Figure 2. A map of the U.S. showing areas where high wind loading may affect the design of structures used to house emergency standby power systems.

acknowledgment of awareness of the special requirements contained in the statement of special inspection.

SEISMICALLY CERTIFIED EMERGENCY POWER SYSTEMS

Emergency standby power system manufacturers are responsible for providing a product that is certified to withstand seismic and high wind loading forces and to continue operating after a seismic event.

The provision in IBC-2015, Section 1705.12.3 Seismic Certification of Non-structural Components states:

> *The registered design professional [usually the architect, consulting engineer or electrical contractor] shall specify on the construction documents the requirements for certification by analysis, testing, or experience data for nonstructural components and designated seismic systems in accordance with Section 13.2 of ASCE 7, where such certification is required by Section 1705.12.*

The key material in ASCE 7-10 Section 13.2.2 Special Certification Requirements for Designated Seismic Systems states:

Figure 3. A typical label on seismically certified generator set referencing the applicable IBC version and upper limit of design spectral response acceleration, S_{DS}.

Certifications shall be provided for designated seismic systems assigned to Seismic Design Categories C through F as follows:

> *Active mechanical and electrical equipment that must remain operable following the design earthquake ground motion shall be certified by the manufacturer as operable whereby active parts or energized components shall be certified exclusively on the bases of approved shake table testing in accordance with Section 13.2.5 or experience data in accordance with Section 13.2.6 unless it can be shown that the component is inherently rugged by comparison with similar seismically qualified components. Evidence demonstrating compliance with this requirement shall be submitted for approval to the authority having jurisdiction after review and acceptance by a registered design professional.*

The manufacturer must label certified products requiring seismic certification identifying them as such and identifying the corresponding certificate of compliance in accordance to 1703.5. Labeling.

> *Where materials or assemblies are required by this code to be labeled, such materials and assemblies shall be approved by an approved agency in accordance with Section 1703.*

The building official or authority having jurisdiction has the responsibility to verify the product to be installed meets the seismic requirements. Section 1705.11.4 Designated Seismic Systems states:

> *The special inspector shall examine designated seismic systems requiring seismic qualification in accordance with Section 1705.12.3 and verify that the label, anchorage or mounting conforms to the certificate of compliance.*

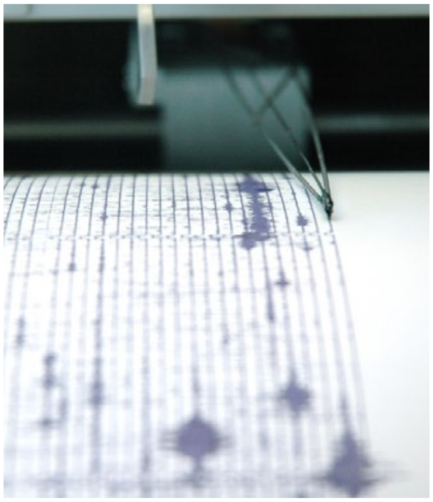
And lastly, Section 1705.12.3 states that those products needing seismic qualifications need to be specified as such on the construction documents:

> *The registered design professional shall specify on the construction documents the requirements for certification by analysis, testing or experience data for nonstructural components and designated seismic systems in accordance with Section 13.2 of ASCE 7, where such certification is required by Section 1705.12.*

An emergency standby power system consists of a base, engine, alternator, fuel supply, transfer switches, switchgear and controls. While the engine generator set is naturally a robust piece of equipment, designing for survival of a seismic event focuses attention on the generator set mounting to the foundation and external attachments, such as fuel lines, exhaust and electrical connections.

To certify the components of an emergency standby power system, the generator set, and its associated systems, is subjected to a combination of three-dimensional shake-table testing and finite element analysis. The IBC requires that these tests be performed by an independent, approved, third-party supplier that can issue a seismic certificate of compliance when the tests are successfully completed. Once a generator set passes the seismic certification test, it is the responsibility of the manufacturer to label the equipment, indicating the seismic forces to which the equipment was subjected. *Figure 3* illustrates a typical label on a seismically certified generator set.

Local regulations may be more stringent
While the general provisions of the IBC have been largely adopted as the de facto building code in many states and localities, the project engineers should consult with local jurisdictions to verify that all applicable local standards have been met. In California, for example, the Office of Statewide Health Planning and Development (OSHPD) has set seismic standards for hospitals and health care facilities in accordance with both the 2016 California Building Code and IBC. While these local codes and recommended seismic testing protocols are largely harmonized with IBC, consultation with local authorities can reduce the risk of installing a system which may ultimately prove to be non-compliant.



Conclusions

While the IBC addresses all facets of structure design and construction in all 50 U.S. states, it also addresses the performance of a number of nonstructural systems, such as emergency standby power systems. The IBC's requirements for emergency standby power systems are intended to ensure that structures within certain occupancy categories will have emergency power after a catastrophic event, such as an earthquake or hurricane. As such, it has set seismic design and testing standards for the manufacturers of emergency standby power systems.

About MTU Onsite Energy

MTU Onsite Energy's standard emergency standby generator sets are available with seismic certification and are suitable for applications in the seismically active areas of the U.S. Its standby generator products have undergone extensive design analysis to enhance survivability in event of earthquakes, and they have been tested and certified by an approved, independent testing organization. Generator set enclosures have been analyzed and certified to resist wind loading up to 190 mph. All certified products are labeled in accordance with 2012 IBC or 2015 IBC.

MTU Onsite Energy has undertaken to have its products certified at the manufacturing level rather than leaving it up to its distributors to manage on a case-by-case basis as is done by some power system manufacturers. MTU Onsite Energy believes that certification at the manufacturing level leads to more uniform performance of the equipment in the field and eliminates the likelihood that in-field modifications will be made to the power system during installation that will compromise its seismic rating or survivability.

Resources:

1. To review or purchase a copy of IBC-2015, go to: www.iccsafe.org.
2. For maps on earthquake zones and short-period response accelerations, go to the United States Geological Survey site: earthquake.usgs.gov/hazards.
3. To learn about independent seismic testing and certification, visit The VMC Group site: www.thevmcgroup.com.

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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 3,600 kilowatts power output (kWe) and gas engines up to 2,530 kWe.