Seismic and wind requirements for generator sets and transfer switches

> White paper

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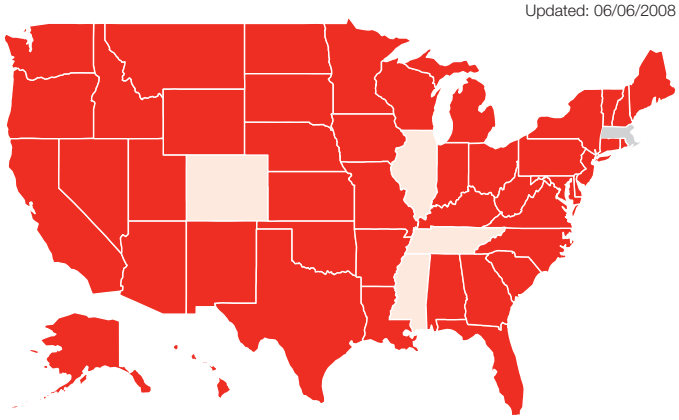
The International Building Code (IBC) provides an up-to-date building code addressing the design and installation of building systems through requirements that emphasize performance. Published by the International Code Council (ICC), this comprehensive code establishes minimum regulations for building systems using prescriptive and performance-related provisions that combine the scope of previously dominant codes, such as BOCA and ICBO Uniform Building Code (UBC).

INTERNATIONAL CODES® ADOPTION INFORMATION

Updated: 06/06/2008



- Adopted and effective statewide
- Adopted by various local jurisdictions
- Adopted with unknown future effective date

FIGURE 1 – United States code adoption as of June 6th, 2008. For map updates, visit www.iccsafe.org/government/adoption.html.

Provided is a summary of the earthquake (seismic) and wind provisions affecting power generation systems that are included in the International Building Code (IBC). For designated building functions, the IBC can require that systems critical to life safety and fulfilling the building's intended purpose remain online immediately after a seismic event. This can affect the backup and emergency system, requiring the system be compliant for the same seismic design category as the building.

For buildings designated as critical, any system required to fulfill the intended use is also covered. Additionally, the code states that a failure of any component shall not cause the failure of any essential component. If a generator set is essential for life safety functions, to protect life safety functions, or for a building to fulfill the intended use; it must be certified compliant to meet the same seismic design category as the building.

As of 6/6/08, the IBC has been:

- Adopted & Effective statewide:
  44 states plus Washington DC
- Adopted by various local jurisdiction:
  MS, DE, CO, IL, TN
- Adopted with unknown future effective date:
  Massachusetts

Old codes (UBC) referenced seismic zones: 0, 1, 2a, 2b, 3 and 4. The seismic design force for equipment installation was the same regardless of where you were located within the zone. With the IBC Code, the zones are no longer valid. The U.S. Geological Survey

Liability concerns: The various versions of the IBC codes hold architects, engineers, contractors and equipment manufacturers responsible for the design and installation of buildings and their corresponding MEP (mechanical, electrical and plumbing) systems. As a state adopts a version of the building code, it becomes the law governing construction within the state. Accordingly, professional licenses are potentially at risk for those that do not adhere to the requirement of the law. The focus of the IBC codes is on building performance. The logic is that if MEP systems are designed to the same seismic design force as the building itself, then those MEP systems will continue to operate after a seismic event.

FIGURE 2 – U.S. spectral response acceleration map

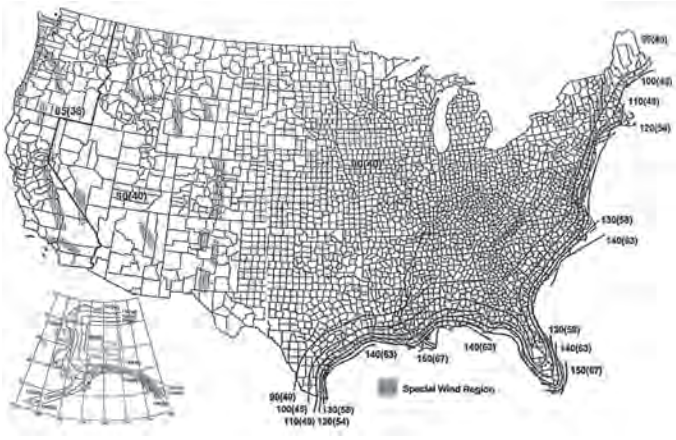


FIGURE 3 – Basic wind speed (3-second gust wind speeds in miles per hour at 33 feet above ground for Exposure C category).

has now mapped the ground accelerations throughout the United States and has assigned various values. Calculating the seismic design force for equipment attachment and equipment selection is now based on these new mapped accelerations (called Short Period Spectral Response Acceleration). Specifying engineers must now be referencing these values in equipment specs and not the old UBC Zones.

The IBC Code also incorporates wind regions. For states that have adopted the IBC 2006, the requirements are that equipment must be attached to the building to handle the overturning forces of wind and must remain operational after being exposed to these wind conditions. For states that have not adopted the IBC 2006, only proper attachment is required.

	2000	2003	2006
Seismic Requirement	Yes	Yes	Yes
Wind Load Requirement	No	No	Yes
Certification by Approved Independent Agency	Yes	Yes	Yes

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Seismic qualifications of mechanical and electrical equipment: The registered design professional in responsible charge shall state the applicable seismic qualifications requirements for designated seismic systems on the construction documents. Each manufacturer of designated seismic system components shall test or analyze the component and its mounting system or anchorage as per IBC 1708.5. Submissions include not only a certificate of compliance, but also installation drawings for review and acceptance by the registered design professional. As an example, drawing 0179-5288 provides anchor size, type, and load requirements. Qualification shall be by an actual test on a shake table, by three-dimensional shock test, by an analytical method using dynamic characteristics and forces, by the use of experience data (i.e, historical data demonstrating acceptable seismic performance) or by a more rigorous analysis providing for equivalent safety.

IBC and seismic requirements

The IBC increases the design professional's responsibility by adding seismic reviews to the standard building structure design and review process. The code provides building life safety systems remain online immediately after a seismic event. For buildings designated as critical, any system required to fulfill the intended use is also covered.

What constitutes a certified seismic-compliant product?

Certification by an approved independent agency. Seismic-compliant products must have been reviewed and certified as capable to withstand a given seismic force by an approved agency. The equipment must withstand specific seismic forces (Fp) on a three dimensional shake table shock test, analytical method using dynamic characteristics, use of historical data, or more rigorous analysis providing for equivalent safety. (IBC 1708.5). Additionally, Section 1702 of the code states that when required by the design professional, a label must be applied to the product that indicates it has been inspected and evaluated by an independent approved agency. The IBC outlines the requirements for an independent approved agency in Section 1703.

Determining requirements

Depending on the version of the code, there are two different seismic design category charts to be referenced. However, the methodology used for determining the seismic design category remains the same for all versions of the code.

Four basic steps are required to determine whether the generator set is required to comply with the seismic-resistance provisions of the IBC:

1. Determine the seismic use group or occupancy category depending on the version of the code.
2. Determine the component importance factor (Ip) of the equipment.
3. Determine the seismic design category of the structure.
4. Determine if the genset or transfer switch is exempt from seismic requirements.

The specifying engineer should include this information in the equipment specs.

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1. Determine the seismic occupancy category:

Category	Nature of Occupancy
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limted to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities
II	Buildings and other structures except those listed in Occupancy Categories I, III, and IV
III	Buildings and other structures that represent a substantiantial hazard to human life in the event of failure, including but not limited to: • Covered structures whose primary occupancy is public assembly with an occupant load greater than 300 • Buildings and other structures with elementary school, secondary school or day care facilities with an occupant load greater than 250 • Buildings and other structures with an occupant load greater than 500 for colleges or adult education facilities • Health care facilities with an occupant load of 50 or more resident patients, but not having surgery or emergency treatment facilities • Jails and detention facilities • Any other occupancy with an occupant load of greater than 5,000 • Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Occupancy Category IV • Buildings and other structures not included in Occupancy Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released
IV	• Buildings and other structures designated as essential facilities, including but not limited to: • Hospitals and other health care facilities having surgery or emergency treatment facilities • Fire, rescue and police stations and emergency vehicle garages • Designated earthquake, hurricane or other emergency shelters • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power-generating stations and other public utility facilities required as emergency backup facilities for Occupancy Category IV structures • Structures containing highly toxic materials as defined by Section 307 where the 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 • Water treatment facilities required to maintain water pressure for fire suppression

Table 604.5 Occupancy Category of Buildings and Other Structures: For the 2003 version, Categories I and II are considered Seismic Use Group I, category III is considered Seismic Use Group II and Category IV is equivalent to seismic use group III.

2. Determine the component importance factor:

A power generation system becomes a designated seismic system based on its Ip and the building's determined seismic design category. The IBC recognizes two values for Ip as related to equipment. They are 1.0 and 1.5. Those architectural, electrical and mechanical systems and their components that require design in accordance with Section 1702.1 have a component importance factor greater than 1.0. The following Ip values, taken from the code, have been interpreted to be relevant: The code does not specifically define what constitutes a "life safety system" or critical component for determining Ip for each seismic use group.

It is the specifying engineer's responsibility to determine what Ip value will be given to a piece of equipment.

Component Type	Importance Factor
The component is required to function for life-safety purpose after an earthquake, including fire sprinkler systems	**1.5**
The component contains hazardous materials	**1.5**
The component is in or attached to an Occupancy Category IV structure and is needed for continued operation of the facility or its failure could impair the continued operation of the facility	**1.5**
All other components	**1.0**

3. Determine the seismic design category

All structures are assigned to a seismic design category based on their seismic use group and determined design spectral response. Use the following steps to arrive at the seismic design category for a structure.

Step 1: Determine the maximum spectral response accelerations (S_s and S_1) for the area where the structure is located.

The maximum considered spectral response acceleration at 0.2 seconds (S_S) and at 1 second (S_1) can be determined using the spectral response maps provided in the printed version of the IBC or the accompanying software which can be found on: http://earthquake.usgs.gov/research/hazmaps/design/

Step 2: Determine the site class (A to F) and site coefficients (Fa and Fv).

Step 3: Calculate the adjusted maximum accelerations (S_{MS} and SM_1).

Using site coefficients Fa and Fv calculate the adjusted maximum spectral response acceleration parameters at 0.2 seconds (S_{MS}) and one second (S_{M1}) as follows:

$$S_{MS} = FaSs * S_{M1} = Fv\ S_1$$

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Step 4: Calculate the design spectral response acceleration parameters (S_{DS} and S_{D1}).

Use the values calculated for S_{MS} and S_{M1} in Step 3 to calculate the design spectral response acceleration parameters at 0.2 seconds (S_{DS}) and one second (S_{D1}) as follows:

$$S_{DS} = \tfrac{2}{3} S_{MS} \bullet S_{D1} = \tfrac{2}{3} S_{M1}$$

Step 5: Determine the assigned seismic design category. The seismic design category can be determined using Tables 1613.5.6 (1) or 1613.5.6 (2) in the printed IBC document and have been reproduced below. The seismic design category is a function of the structure's designated seismic use group and the values for SDS or S_{D1} calculated in Step 4.

Site Class	Soil Profile Name	Average Properties in Top 100 Feet See Section 1613.5.5		
		Soil Shear Wave Velocity, $\bar{v}_s$ (ft/s)	Standard Penetration Resistance, $\bar{N}$	Soil Undrained shear strength, $\bar{s}_u$ (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 < \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \geq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s \leq 600$	$15 \leq \bar{N} \leq 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity Index $PI > 20$ 2. Moisture Content $w \geq 10\%$, and 3. Undrained Shear Strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils Peats and/or highly organic clays ($H > 10$ feet of peat and.or highly organic clay where H = thickness of soil) Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) Very thick soft/medium stiff clays ($H > 120$ Feet)		

Table 1613.5.2 Site Class Definitions

For SI: 1 foot = 304.8mm, 1square foot = 0.0929m², 1 pound per square foot = 0.0479 kPa

Site Class	Mapped Spectral Response Acceleration at Short Period				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	10.
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	*b*	*b*	*b*	*b*	*b*

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period S

b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7

Table 1613.5.3 (1) Values of Site Coefficient F_a [a]

Site Class	Mapped Spectral Response Acceleration at 1-Second Period				
	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1..7	1.6	1.5	.14	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	*b*	*b*	*b*	*b*	*b*

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at 1-second period S

b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7

Table 1613.5.3 (1) Values of Site Coefficient F_v [a]

Value of S_{DS}	Occupancy Category		
	I or II	III	IV
$S_{DS} < 0.167$g	A	A	A
$0.167\text{g} \leq S_{DS} < 0.33$g	B	B	C
$0.33\text{g} \leq S_{DS} < 0.50$ g	C	C	D
0.50 g $< S_{DS}$	D	D	D

Table 1613.5.6 (1) Seismic Design Category Based on Short-Period Response Accelerations

Value of S_{D1}	Occupancy Category		
	I or II	III	IV
$S_{D1} < 0.067$g	A	A	A
$0.067\text{g} \leq S_{D1} < 0.133$g	B	B	C
$0.133\text{g} \leq S_{D1} < 0.20$g	C	C	D
0.20g $< S_{D1}$	D	D	D

Table 1613.5.6 (1) Seismic Design Category Based on 1-Second-Period Response Accelerations

About the author

Aniruddha Natekar started with Cummins Power Generation in 2007. As a Sales Application Engineer, he provides technical recommendations on installations, engineering support to customers, assists the sales force with technical training, and supports technical seminars.

Aniruddha has M.S. in Automotive Engineering from Lawrence Technological University (Southfield, MI) and B.S. in Mechanical Engineering from University of Pune (India). He has held positions in R&D, market research, engineering, and product development with various automotive companies.

4. Determine if the generator set or transfer switch is exempt from seismic requirements.

Check for applicable exemptions. The following components may be exempt from complying with the code:

- Mechanical and electrical components in seismic design category B.
- Mechanical and electrical components in seismic design category C provided that the component importance factor Ip = 1.0.
- Mechanical and electrical components in seismic design category D, E, F where the component importance factor is 1.0 and either:

  a. Flexible connections between components and associated ductwork, piping and conduit are provided.

  b. Components are mounted at 4 feet (1.22 m) or less above the floor level and weigh 400 lb (1780 N) or less.

Additional IBC information and resources

The following chapters in the IBC describe the requirements for seismic design and equipment certification:

- Chapter 16 describes the requirements for seismic-resistant design. Code requirements and methodology are based on data developed in the 1997 National Earthquake Hazards Reduction Program (NEHRP) which was funded by the Federal Emergency Management Agency (FEMA). Section 1613 states the requirement to provide a compliant system.
- Chapter 17 describes the certification, testing and inspection requirements. It also covers requirements for special inspections, quality assurance plans, etc. Section 1702 defines Certificate of Compliance and Section 1703 states the requirements and definition of approvals, including approved agency and labeling.

The following resources provide information and assistance with the IBC and seismic requirements:

- A printed version of the 2006 IBC and software CD can be ordered online at www.iccsafe.com
- The U.S. Geological Survey provides spectral maps on its website at http://eqhazmaps.usgs.gov/.
- The Building Seismic Safety Council of the National Institute of Building Sciences (NIBS) provides its National Earthquake Hazards Reduction Program (NEHRP) recommended provisions for seismic regulations for new buildings and other structures (FEMA 450) at http://www.bssconline.org.

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