

Understanding IBC Wind Load Requirements for Generating Systems

By:

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It is important for standby power system enclosures to withstand loads produced by hurricanes and wind storms. These enclosures must be designed to endure the forces of wind loads that are determined by many complex factors. Standards have been created to establish common methodology for design and analysis to minimize losses due to wind events. Building standards have evolved for decades in the United States, along with codes for electrical and mechanical systems. The latest edition of building standards is embodied in the International Building Code (IBC 2000, 2003, 2006, and 2009), which sets requirements for structures and ancillary systems, including standby power systems. The purpose of this paper is to familiarize building owners and power system specifiers with the wind load compliance provisions of the IBC with respect to power system equipment.

INTERNATIONAL BUILDING CODE (IBC)

In 2000, the International Code Council (ICC) issued its first version of the IBC. While most of the IBC deals with life-safety and fire protection of buildings and structures, it also addresses wind load design requirements for both buildings and components attached to them. The IBC has been updated every three years and each edition references standards from a variety of sources, such as the design requirements originally promulgated by the American Society of Civil Engineers (ASCE 7-05) in its Minimum Design Loads for Buildings and Other Structures.

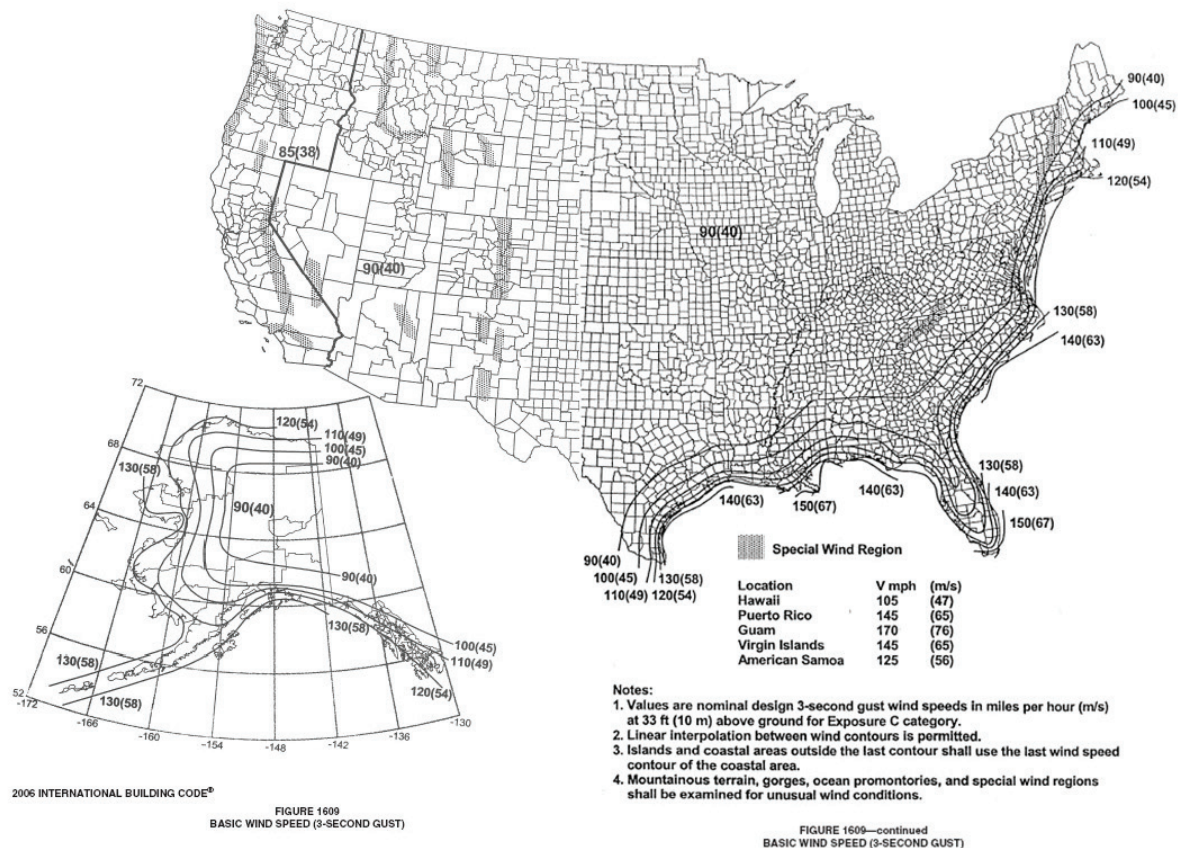
While the IBC has an “international” label, currently, it only refers to building standards in the United States. All states and many local authorities have adopted one version of the IBC, either the 2000, 2003, 2006 or 2009 edition. Most states have adopted the code at the state level and other local governments have adopted versions of the code at the municipal or county level. The vast majority of states have adopted the 2006 version, while fewer states have adopted the 2003 edition and several are still referencing the 2000 version. Several United States territories have adopted the 2009 version which is now available for state adoption. While the IBC is not a government mandate, its adoption has been encouraged—and in some cases

required—to ensure funding coverage by the Federal Emergency Management Administration (FEMA). Generally speaking, the requirements for wind load design are very similar regardless of which version of the code a state has adopted. The following link provides information on the IBC adoption status for each state: <http://www.iccsafe.org/gr/Documents/stateadoptions.pdf>.

The United States wind speed map provides information on basic wind speed in miles per hour in geographic zones. The first step to identifying wind load requirements for a standby power system is to determine the installation location's basic wind rating speed. While most of the United States has a basic wind rating speed of 90 miles per hour, special regions, particularly along the Atlantic and Gulf coasts, have ratings of up to 150 miles per hour. Figure 1 shows basic wind speed versus geographic regions in the United States.

Figure 1: IBC Basic Wind Speeds

Source: ASCE 7-05, figure 1



QUALIFYING THE PRODUCT

Manufacturers have three options to qualify their product: wind tunnel testing, analytical calculation, or a combination of both. Wind tunnel testing is often not practical due to size and wind speed constraints. Even a small standby power set, such as 20 KW, would be too large for the vast majority of wind tunnels. Also, huge power requirements for blower fans and massive tunnel size make testing of larger sets virtually impossible.

Since wind tunnel testing is not practical, qualification is done most often using the analytical method. Using the IBC 2009 version and applying the proper conditions, analysis can be done to qualify sets for 2000, 2003 and 2006 versions simultaneously. Specifically, the IBC 2006 and 2009 versions specify application of methods in ASCE 7-05 section 6.5. These methods are detailed and rigorous.

PARAMETERS DETERMINE WIND LOADS

Analytical calculation uses formulas identified in the ASCE 7-05, Minimum Design Codes for Buildings and Other Structures, an industry-wide standard. The first step is to calculate the wind velocity pressure at the structure which is dependent on geography, local terrain, topography, the direction factor and the occupancy of the structure. In plain language the analysis begins with anticipated wind speed and converts that to the wind pressure. The challenge is to take the complex set of many variables for each installation and simplify it to an equation with standard parameters. Per section 6.5.10 of ASCE 7-05, wind velocity pressure at the structure is defined as:

$$qz = .00256KzKzKdV2Ip \text{ (lb/ft}^2\text{) (ASCE 7-05 equation 6-15)}$$

The five critical parameters used to establish the wind load are:

V – The basic wind speed is defined at 33 feet above ground level and dependent on the geographic location. See figure 1.

Kz – The exposure factor is dependant on installation height above ground and local terrain. As the building installation elevation increases, so does the wind speed; hence an amplification factor as installation height increases. This factor is as high as 1.89 for top of building installations.

Kzt – The topographic factor is dependent on the gross terrain. As wind speed increases with elevation of a building, so to, wind speed increases with height up a hill. For flat terrain, this value is approximately 1.0. Conversely, the factor can approach 3 on a hill due to increasing wind speed with elevation. Kzt ranges from 1 to approximately 3.

Kd – The direction factor ranges from 0.85 to 0.95. It is dependent on the type and portion of the structure. For rectangular structures, which include generator set enclosures, the value is .85.

Ip – The “importance” factor is used to reduce or amplify the basic wind speed; it is dependant on the occupancy factor of the structure. This ranges from .77 for uninhabited buildings to as high as 1.15 for buildings of critical importance such as hospitals, fire stations and the like.

Once the wind velocity pressure has been determined, it is applied with adjustment factors per the standard, to the sides and roof of the structure. The windward side receives a positive pressure, while the remaining walls and roof receive a negative pressure. Negative pressure attempts to suck the sides off the building, while positive pressure tends to compress the building. The combination of internal and external pressures establishes the actual wind design pressures used for analysis on respective walls and roof. The combined pressures are defined by the following formula also part of ASCE 7-05, section 6.5.10:

$$P = qGC_p - q_i(GC_{pi}) \text{ (lb/ft}^2\text{) (ASCE 7-05 equation 6-17)}$$

q_z – Wind velocity pressure as calculated above.

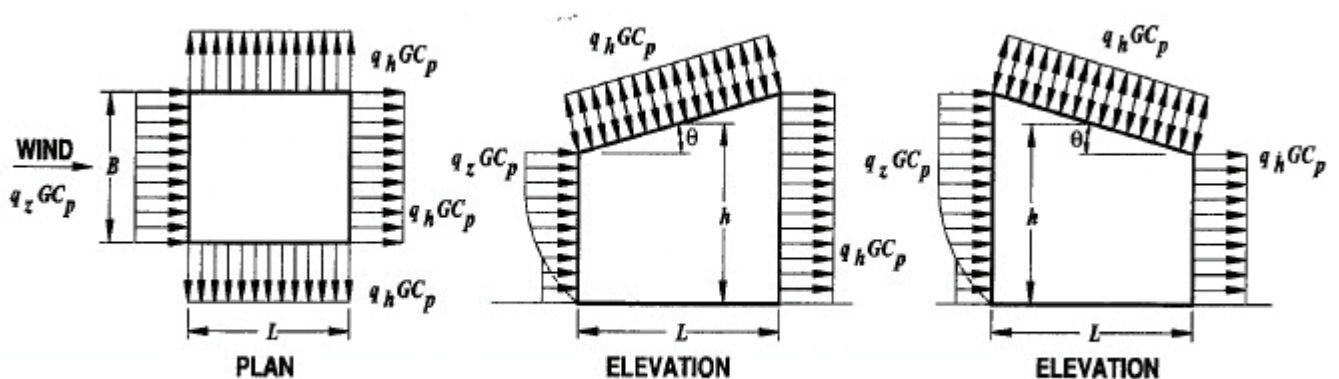
G – The gust effect factor and as applied to generator set enclosures, is 0.85 by definition of ASCE 7-05, section 6.5.8.

C_p – The external pressure coefficient which is dependent upon the specific geometry and

proportion of the enclosure and is determined by comparison to predefined geometric proportions relative to charted C_p values in figure 6.6 of the ASCE 7-05.

C_{pi} – The internal pressure coefficient and predefined by ASCE 7-05 and is dependent upon the proportion of the area of the openings of the enclosure to the overall enclosure area. Openings in a building envelope create holes for airflow which creates internal pressure.

Thus qGC_p is the external for pressure value. It is necessary to calculate this for each external surface. See figure 2 for a typical distribution of pressures on the surfaces of a standby power system. The term $q_i(GC_{pi})$ is for pressure developed on the inside of the structure. Cracks and gaps in structure allow air to penetrate it and internally pressurize the enclosure. Term q_z calculated in equation 6-15 is substituted for q and q_i in equation 6-17. With P established for each surface, the pressure can then be applied to the respective surfaces and stresses and loads evaluated for adequacy.



MONOSLOPE ROOF (NOTE 4)

Figure 2: Typical External Pressure Profiles
Source: ASCE 7-05

Stresses are checked to make sure material does not fail. The structure is evaluated to make sure it does not buckle or collapse, and fasteners are evaluated against calculated loads to make sure they do not break. One method engineers use to evaluate the enclosure to assure compliance is to develop a deflection plot which visually confirms the computer numerical analysis of the impact of pressure on the enclosure. Figure 3 is a deflection plot of an enclosure subjected to a 150 mile per hour basic wind speed.

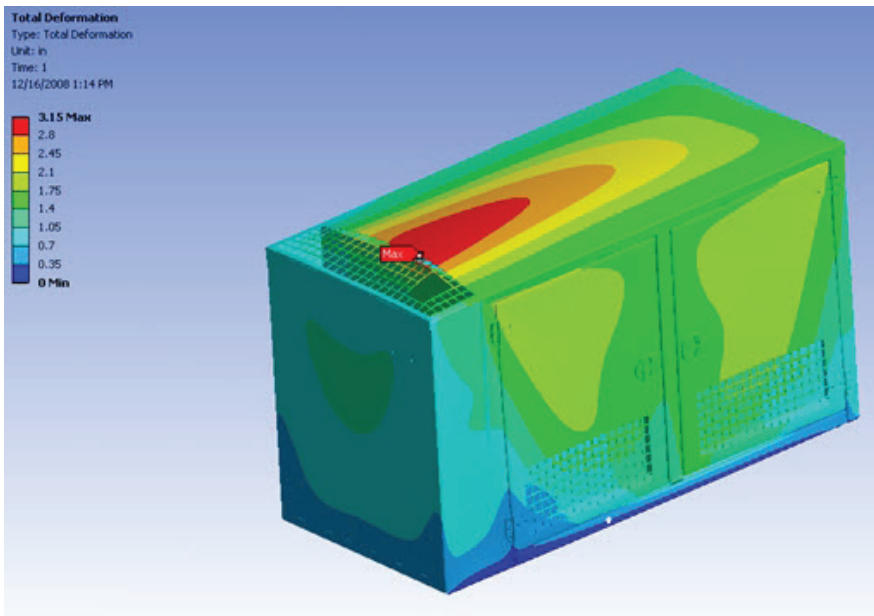


Figure 3: Analytical Deflection Plot Due to Basic Wind Speed Load on Enclosure
Source: Kohler Power Systems

INSTALLATION AND MOUNTING CONSIDERATIONS

Of equal importance to the design of the power system is installation and mounting of the enclosure to ensure that the product remains connected to the foundation through the storm. The installing contractor is responsible for proper specification and installation of all anchors and mounting hardware.

GENERAL WIND LOAD INSTALLATION NOTES

- Anchors used for wind load installation must be designed and rated to resist wind loading in accordance with ACI (American Concrete Institute) 355.2-04 and documented in a report by a reputable testing agency (i.e. The Evaluation Service Report issued by the International Code Council). Anchors brands and style used for wind loading are essentially the same as those for seismic loading.
- Anchors must be installed to a minimum embedment depth of eight times the anchor diameter.
- Anchors must be installed in minimum 4000 psi compressive-strength normal-weight concrete. Concrete aggregate must comply with ASTM (American Society for Testing and Materials) C33. Installation in structural lightweight concrete is not permitted unless otherwise approved by the structural engineer of record.
- Anchors must be installed to the required torque specified by the anchor manufacturer to obtain maximum loading.
- Anchors must be installed with spacing and edge distance required to obtain maximum load unless otherwise approved by the structural engineer of record.
- Wide washers must be installed at each anchor location between the anchor head and equipment for tension load distribution. See the applicable installation or dimension drawing for specific anchor information and washer dimensions.

- Equipment installed on a housekeeping pad requires the housekeeping pad thickness to be at least 1.5 times the anchor embedment depth.
- All housekeeping pads must be securely anchored and dowelled or cast for security and approved by the structural engineer of record. Rebar reinforcing in the housekeeping pad is required for all installations.
- Rebar reinforcement in concrete must be designed in accordance with ACI 318-05.
- Wall-mounted equipment must be installed to a rebar-reinforced structural concrete wall that is wind load designed and approved by the engineer of record to resist the added wind loads from components being anchored to the wall. When installing, rebar interference must be considered.
- Structural walls, structural floors and pads must also be designed and approved by the structural engineer of record. The installing contractor is responsible for proper installation of all electrical wiring, piping, ducts and other connections to the equipment.

CONCLUSION

When specifications call for IBC wind rated products, it is necessary to verify product has been tested or analyzed for IBC compliance. Since analysis is detailed, it can be very expensive for a 'one-off' job specific basis. In addition to the expense, the lead time on a 'one-off' project can be prohibitive. Therefore, look for products that have been prequalified to IBC requirements to save time and expense on your project. Once you have chosen your product be sure to follow the installation requirements to ensure IBC rated performance of the standby power system installation.



ABOUT THE AUTHOR

Allan Bliemeister is a Senior Staff Engineer with Kohler Power Systems-Americas. He holds a BSME from the University of Wisconsin-Milwaukee, and a MSME from the University of Wisconsin-Madison. He's been with Kohler since 1988, and specializes in International Building Code issues, finite-element modeling, stress and fatigue analysis, and vibration.

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