IBC Wind Load Requirements for Power Systems

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INTRODUCTION

It is important for standby power system enclosures to withstand loads produced by hurricanes and windstorms. 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 and codes for electrical and mechanical systems have evolved for decades in the United States. The latest edition of building standards is embodied in the International Building Code (IBC), 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)

While generators have been paralleled for more In 2000 the International Code Council (ICC) issued its first version of the IBC. While most of the IBC deals with 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 7–16) 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 IBC. 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. While the IBC is not a government mandate, its adoption has been encouraged—and in some cases required—to ensure funding from 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: https://www.iccsafe.org/wp-content/uploads/Master-I-Code-Adoption-Chart-1.pdf.

The United States wind speed map provides information on basic wind speed in miles per hour in geographic zones. The basic wind speed maps are categorized based on Risk Category I, II , III, and IV. Risk Category is selected based on the Use or Occupancy of Buildings and Structures. Please refer to ASCE 7–16, Table 1.5-1 for details. Standby power systems are usually considered in Risk Category II or III and IV. *Figures 1 and 2* show basic wind speed versus geographic regions in the United States for Risk Category II, III, and IV, respectively. The first step is to identify the Risk Category based on the Use or Occupancy factor per ASCE 7–16. Table 1.5-1 is used to determine the installation location's basic wind rating speed. While most of the United States has a basic wind rating speed of 110 miles per hour, special regions, particularly along the Atlantic and Gulf Coasts, have ratings of up to 200 miles per hour. *Figure 1* shows basic wind speed versus

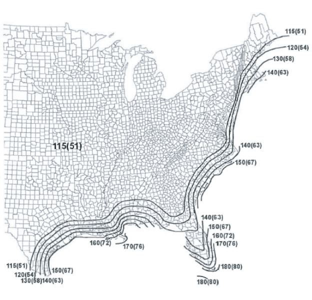

Figure 1.1 IBC Basic Wind Speeds: Basic Wind Speeds: Risk Category II.
Source: ASCE 7-16

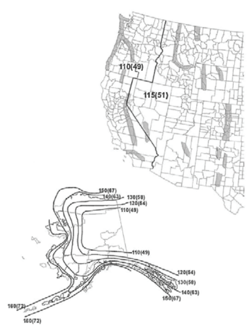

Figure 1.2 IBC Basic Wind Speeds: Basic Wind Speeds: Risk Category II.
Source ASCE 7-16

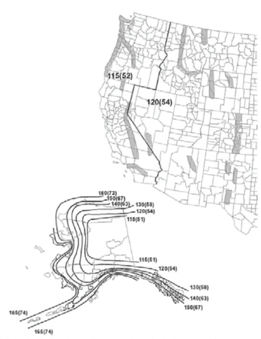

Figure 2.1 IBC Basic Wind Speeds: Basic Wind Speeds: Risk Category III and IV.
Source: ASCE 7-16

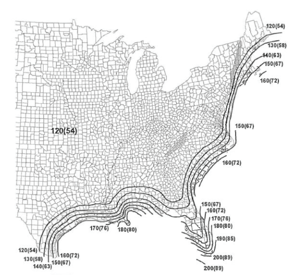

Figure 2.2 IBC Basic Wind Speeds: Basic Wind Speeds: Risk Category III and IV.
Source: ASCE 7-16

QUALIFYING THE PRODUTS

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 generator, 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 standard and applying the proper conditions, analysis can be done to qualify generators and previous versions simultaneously. Certain versions specify application of methods in ASCE 7–16 Chapters 26 and 28 that also qualify previous versions. These methods are detailed and rigorous.

PARAMATERS DETERMINE WIND LOADS

Figure 1 Analytical calculation uses formulas identified in the ASCE 7–16, Allowable Stress Design (ASD) 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 26.10.2 of ASCE 7–16, wind velocity pressure at the structure is defined as:

qz = 0.00256KzKztKdV2 (lb/ft2) (ASCE 7-16 equation 26.10-1)

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

V –The basic wind speed in miles per hour is defined at 33 feet above ground level and dependent on the geographic location. See *Figure 1.*

Kz – The exposure factor is dependent on installation height above ground and local terrain. As the building installation elevation increases, so does the wind speed; creating an amplification factor based on 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, wind speed also increases with height up a hill. For flat terrain, this value is approximately 1.0. Conversely, the factor can approach 3.0 on a hill due to increasing wind speed with elevation. Kzt ranges from 1.0 to approximately 3.0.

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 0.85.

Once the wind velocity pressure (qz) 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 pulls the sides and the roof of the building outward, 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 7–16, Section 27.3.1.

P=qGCp-qi(GCpi) (lb/ft2) (ASCE 7–16 equation 27.3-1)

qz – Wind velocity pressure as calculated above

G – The gust-effect factor, see ASCE 7–16, Section 26.11

Cp – Cp external pressure coefficient from ASCE 7–16, Figures 27.3-1, 27.3-2, and 27.3-3

Cpi – GCpi = internal pressure coefficient from ASCE 7–16, Table 26.13-1

GCpi = internal pressure coefficient from ASCE 7-16, Table 26.13-1

Thus qGCp is the external for pressure value. It is necessary to calculate this for each external surface. See *Figure 3* for a typical distribution of pressures on the surfaces of a standby power system. The term qi(GCpi) 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. The term qz calculated in equation 26.10–1 is substituted for q and qi in equation 27.3–1. With P established for each surface, the pressure can then be applied to the respective surfaces and stresses and loads evaluated for adequacy. 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 ensure compliance is to develop a deflection plot which visually confirms the computer numerical analysis of the pressure on the enclosure. *Figure 4* is a deflection plot of an enclosure subjected to a 181–mph basic wind speed.

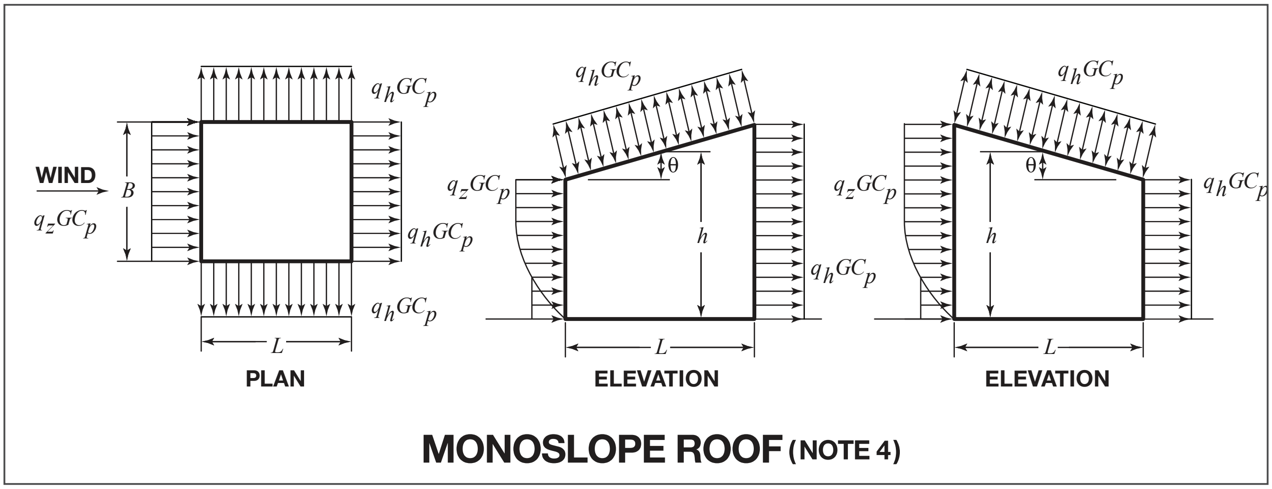

Figure 3. Typical External Pressure Profiles
Source: STANDARD ASCE/SEI 7–16

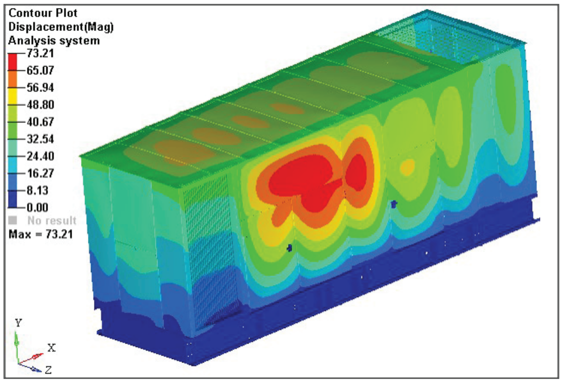

Figure 4: Analytical Deflection Plot Due to Basic Wind Speed Load on Enclosure
Source: Rehlko

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 wind event. 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, for example, the Evaluation Service Report issued by the International Code Council. Anchor 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 concrete pads requires the pad thickness to be at least 1.5 times the anchor embedment depth.
- All concrete pads must be tied into the building's structural slab and approved by the structural engineer of record. Reinforcing bar is required for all concrete pads used for generator set installations.
- Reinforcing bar 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 designed and approved for wind load 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

Luke Dykstra is a staff engineer and holds a bachelor of science degree in mechanical engineering from University of Wisconsin–Platteville. Luke joined Rehklo in 2013 as a manufacturing engineer, then managed the custom generator solutions team, and is currently on the structural Finite Element Analysis (FEA) team. His primary focus in on finite element modeling, non-linear, seismic, and fatigue simulations. He also specializes in IBC and ICC matters. Prior to Rehlko he did non-linear simulation on lattice crawler cranes.

ABOUT POWER SYSTEMS

Power Systems, Rehlko's largest division, delivers worldwide energy solutions designed to ensure resilience for mission-critical applications of all sizes. Building on more than a century of expertise and dedication, the company offers complete power systems, including industrial backup generators (HVO, diesel, gaseous), enclosures, hydrogen fuel cells systems, automatic transfer switches, switchgear, monitoring controls, genuine parts and end-to-end services. As a global company with service partners in every country, Power Systems provides reliable, cutting-edge technology to keep industries and businesses running.
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ABOUT REHLKO

A global leader in energy resilience, Rehlko delivers innovative energy solutions critical to sustain and improve life across home energy, industrial energy systems, and powertrain technologies, by delivering control, resilience and innovation. Leveraging the strength of its portfolio of businesses – Power Systems, Home Energy, Uninterruptible Power, Clarke Energy, Heila Technologies, Curtis Instruments, and Engines, and more than a century of industry leadership, Rehlko builds resilience where and when the grid cannot, and goes beyond functional, individual recovery to create better lives and communities, and a more durable and reliable energy future.