INTERNATIONAL CONFERENCE on Wind Energy Harvesting

April 20-21, 2017
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Paper book: ISBN 978-989-99226-4-8
Electronic book: ISBN 978-989-99226-5-5

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THE INTERNATIONAL CONFERENCE ON
WIND ENERGY HARVESTING 2017
20-21 April 2017
Coimbra, Portugal

Paper 312

NUMERICAL STUDY OF VIBRATIONS IN A STEEL BUILDING INDUCED BY ROOF MOUNTED SMALL SCALE HAWT

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ABSTRACT

One of the most important acceptance issues regarding implementation of the small-scale wind turbines in urban environments is related to the people's quality of life. Human perception of vibrations is very sensitive and therefore turbine induced vibrations can have big influence on the implementation of urban wind harvesting by small-scale turbines at the top of buildings. The aim of this work is to investigate increase of vibrations in a steel building after installation of small-scale turbine at the roof. Comparison is made between floor vibrations influenced by wind action on the building only and together with the roof mounted turbine. Five storey steel building with regular shape is analysed with horizontal axis wind turbine (HAWT) on top with rotor diameter of 5 m. Turbulent wind profile is generated and used in time-history analysis of the building. Results of the analysis in terms of accelerations are compared to the requirements in relevant design codes.

INTRODUCTION

Demands for higher energy efficiency and use of renewable energy resources are constantly increasing. Harvesting of wind energy as a renewable energy resource tends to installation of small-scale wind turbines in urban environments. Installation of small-scale wind turbines in urban regions can gain higher energy efficiency, considering that energy production takes place at the place of its consumption.

Implementation of wind turbines in urban environments has often been compromised by public resistance. Some of the most important issues regarding implementation of wind turbines in urban environments are related to the noise pollution and increased vibrations in buildings. Due to the lack of open free areas in urban regions, installation of wind turbines at buildings is the most possible solution. In case of installation of small-scale wind turbines on existing facilities the increase of floor vibrations can compromise their installation. Human perception of floor vibrations and uncompromised serviceability of equipment in buildings are the two most important acceptability criteria considering increased floor vibrations. Human response to floor motion is very complex phenomenon and it is often related to the combination of factors such as: magnitude of motion, the surrounding environment and the type of human activity which takes place at that moment.

Analysis of relative increase of floor vibrations in a steel building after installation of a small-scale wind turbine on the building's roof is presented in this paper. Five storey steel building with steel-concrete composite floor deck structure is analysed with and without 5 m rotor diameter HAWT considering turbulent wind profile with mean flow speed of 7 m/s. Also, possible increase of floor vibrations is compared with current design requirements for floor vibrations, given in ISO 10137:2007 [4].

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METHODOLOGY

The time-history response of the building to the dynamic load excitation by the wind action is analysed in Sofistik FE software. Dimensions of the building's base are 24x40 m and the height of the building is 18 m, as shown in Figure 1. Steel-concrete decks are composed by 330 mm high steel I beams connected by shear connectors to the 160 mm thick concrete deck. Horizontal stability of the building in longitudinal and transversal direction is achieved by moment resisting frames and vertical bracing, respectively, as shown in Figure 1. Design of the case study building is performed according to requirements given in EN1994:2004 [1] and EN1993:2005 [2] in order to provide a real case design and mass vs. stiffness properties of the structure.

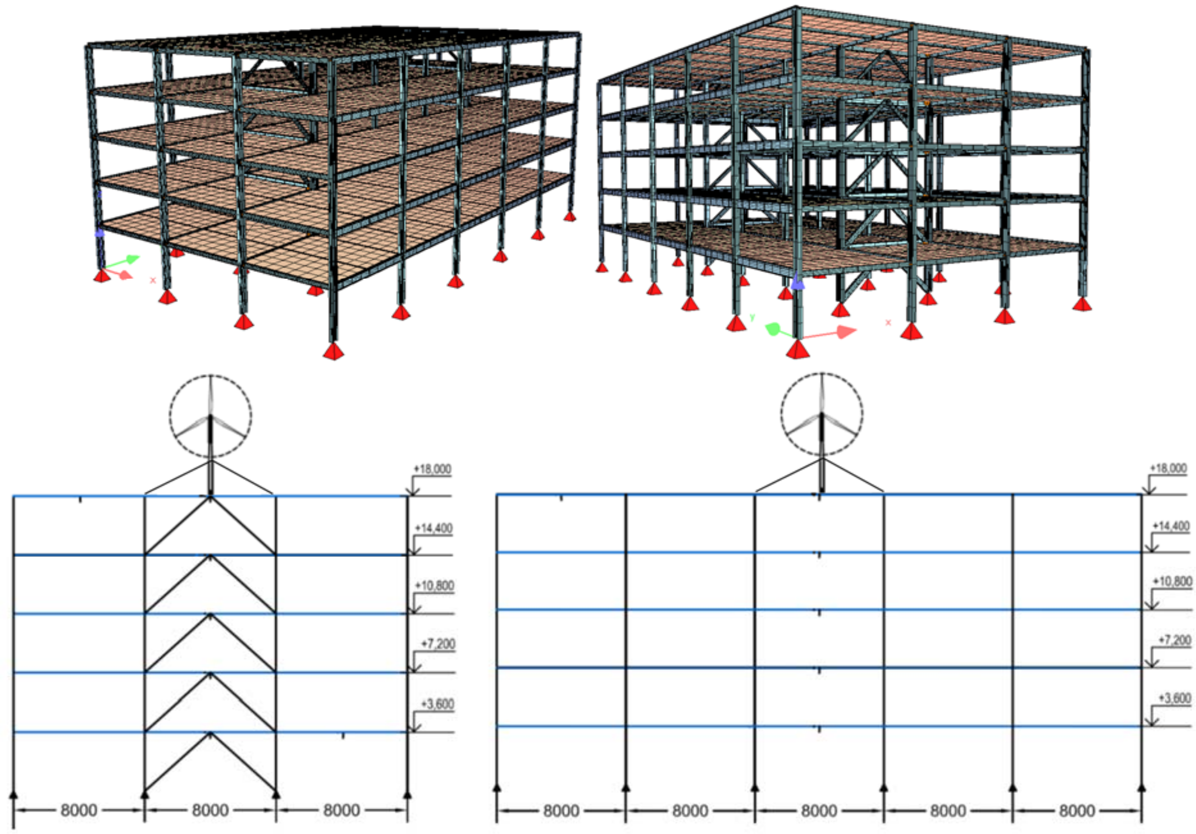

Figure 1. Dimensions of steel building and arrangement of constructive elements

Turbulent wind profile and aerodynamic loads analysis of the turbine is done in a multi-body analysis software package Ashes, see Figure 2. Ashes software integrates finite element analysis (FEA) and blade element momentum (BEM) theory.

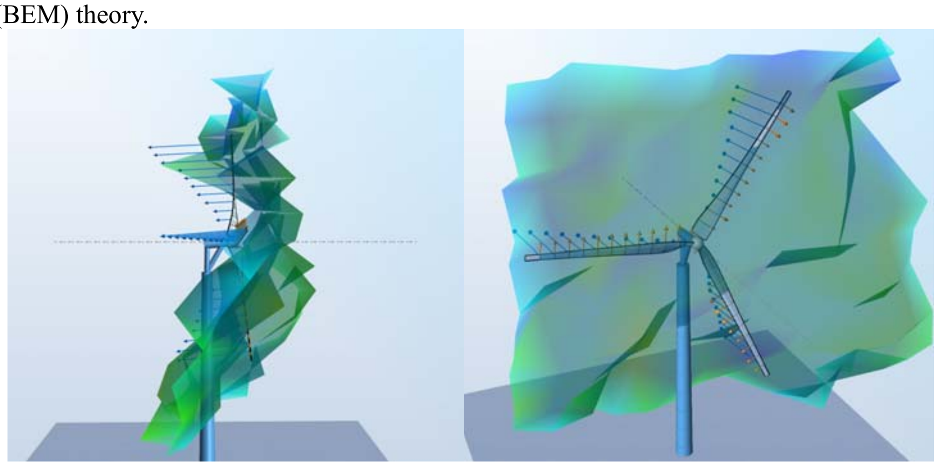

Figure 2. Model of the turbine and the tower in Ashes software.

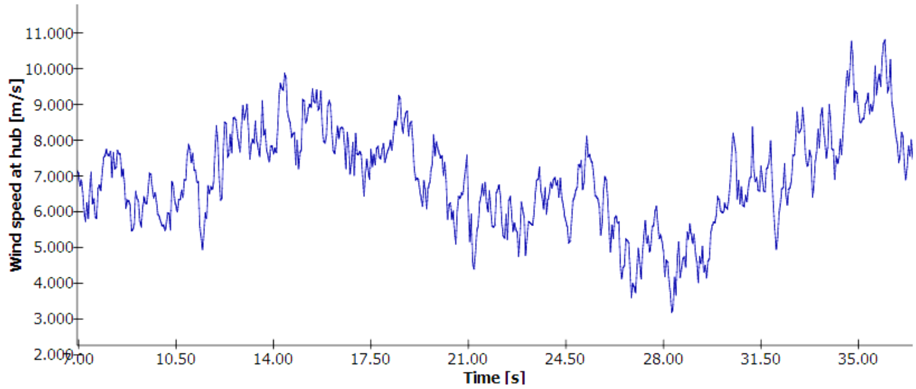

Figure 3. Turbulent wind time history loading generated by TurboSim in Ashes software.

The wind action on the building in two orthogonal directions shown in Figure 1 is applied as a time-history loading of uniform wind pressures corresponding to wind speed shown in Figure 3. External and internal pressure coefficients for building's walls and roof are adopted according to the recommendations given in EN1991:2005 [3], as shown in Figure 4. Loads arising from operation of the turbine are applied as time-histories of forces and bending moments calculated in time-history analysis of the tower and the turbine in Ashes software using spatial wind profile as loading having the mean wind flow identical as shown in Figure 3.

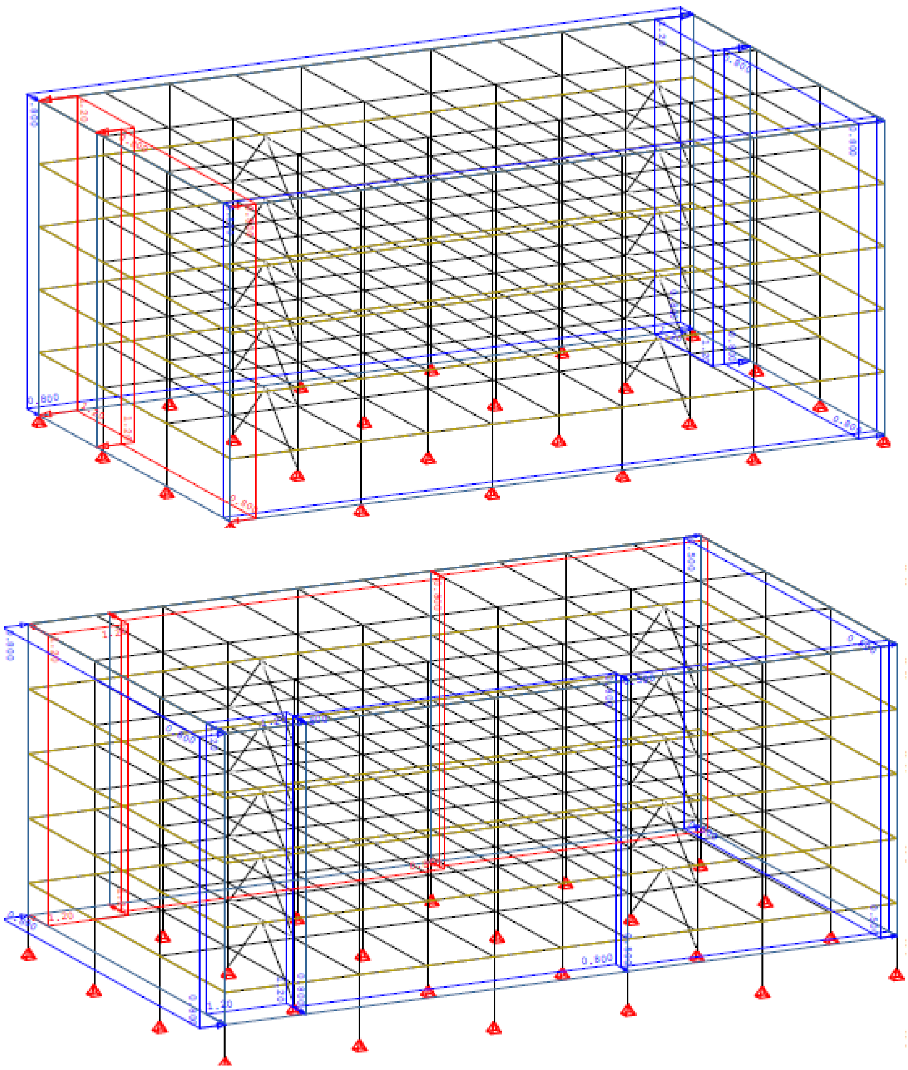

Figure 4. External and internal pressure coefficients for wind actions

RESULTS

Analysis of vibrations for each floor induced by wind action is performed through time-history analysis and extreme accelerations and displacements are obtained. Frequencies of oscillations of each floor are also obtained, which is very important for comparison with design requirements for floor vibrations, e.g. ISO 10137: 2007 [4].

CONCLUSIONS

Increasing demands for installation of wind turbines on the building's roof in urban regions can be compromised due to increase of floor vibrations in buildings. Because of very sensitive human perception of floor vibrations, a detailed analysis of floor vibrations increase caused by installation of wind turbines for urban wind harvesting is required. The level of increase of floor vibrations after installation of small-scale wind turbines at the building's roof is determined in this paper and compared to design code requirements.

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