ANNUAL REPORT | 2013-2014

Western

WindEEE Research Institute
Engineering, Energy & Environment

WindEEEE 2013 - 2014

Preface

At the end of its first three years the **WindEEE Research Institute** has achieved most of the goals set for a period of 5 years at its first Annual Research Meeting (January 2012). The WindEEE Research Institute has been renewed in July 2014 for a period of 5 years "recognizing the excellent progress that has been made with the Institute […] and the research it carries out, is a key strategic priority for Western" (VP Research).

The Construction of the WindEEE Dome is finished and we are in the final stage of the Commissioning process. In parallel the first contract-research projects are already in and have been targeted to demonstrate WindEEE's unprecedented capacity. The governing, fee structure and an initial business model have been established.

The membership for the Institute is established and under a constant growth at Western, nationally and internationally. The research impact measured directly in the number of annual publications, the total funding and the number of HQP supervised has been healthy and constantly growing. The Institute started acting as a multiplier of the research outcomes of its members. Even before commissioning the Institute has managed to attract Industry partnerships both through contract and research grant collaborations.

WindEEE RI has been recognized as an "infrastructure with national character" by the NSERC WESNet Strategic Network and it is currently under consideration by the Government of Canada for National status. At the International level the Institute has now signed a variety of Memorandum of Understandings with outstanding partners in Europe, Americas and Asia. The fruits of these partnerships started to show already as WindEEE RI is now an official applicant (based on its uniqueness) to the largest European research funding programs, Horizon 2020. Also, in 2014 the first International students started to come and work on co-funded research programs with WindEEE. So far graduate students from Germany, Denmark, France, USA and potentially China are expected to do research work in WindEEE. Also Visiting Scholars are under planning at this point.

The WindEEE Research Institute is growing to be a transformative vehicle to foster growth and interdisciplinary excellence inside the new Advanced Manufacturing Park. WindEEE RI will bring its contribution to establish Western as one of the top-five research-intensive universities in Canada, making Western a destination for the best Canadian and international students seeking graduate student research positions, and to raise Western's international profile by establishing itself as a top wind research enterprises worldwide.

Horia Hangan

London, November, 2014

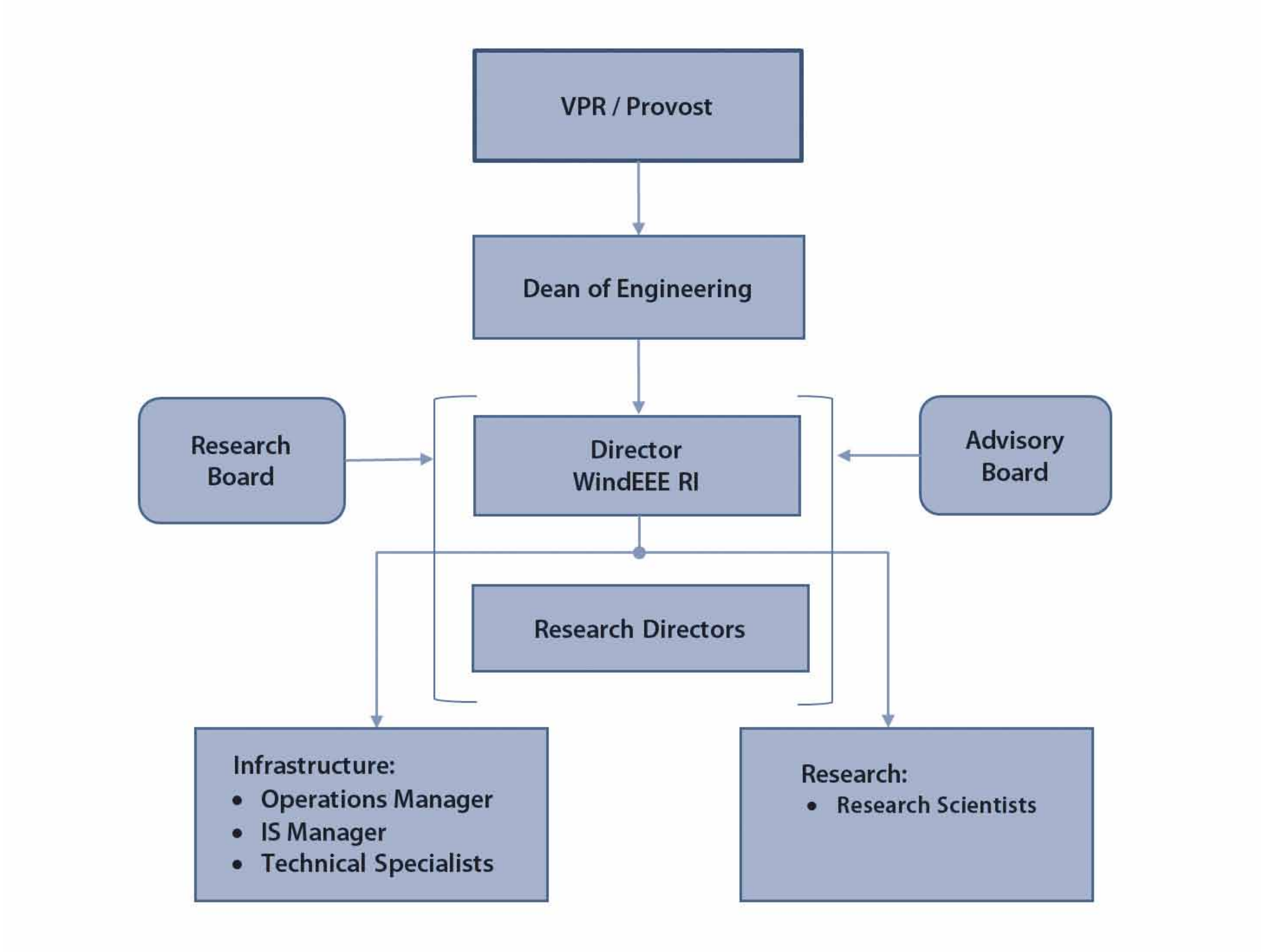
our vision
to be a global leader in wind research and innovation

Governance Structure

The **Governance Structure** provides both internal and external direction, innovative input and expert advice to the Institute in order to facilitate its development at Western and towards a National and International Institute. The Director of the Institute reports to the Dean of Engineering. Two external Boards provide the necessary inputs to the Director of the Institute: the Advisory and the Scientific Boards.

The **Advisory Board** (AB) advises the Board of Directors of the Institute on the progress and advancement in areas related to WindEEE research and services with a global perspective along with providing advice on potential sources of funding in order to primarily address the non-IOF expenditures of the Institute and Facility. The Advisory Board will meet once a year starting 2014 and Members from Industry, Government and Academia are nominated for three (3) year terms. They are listed in WindEEE RI Advisory Board.

The **Research Board** (RB) advises the Director and the Research Directors on the progress and advancement of the wind engineering, energy and environment sectors, with a scientific perspective. The Research Board normally meets once a year and reviews the Research Proposals to qualify for WindEEE IOF funding. The Members of the Research Board of the WindEEE RI are nominated for three (3) year terms and have been now approved at the 2nd Annual Research Meeting in January 2014. They are listed in **WindEEE RI Research Board**.



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Visiting Scholars, Postdoctoral Fellows, Graduate and Exhange Students

Dr. H. Aboshosha – Postdoctoral Fellow, supervisor: Dr. A. El Damatty
Response of Transmission Line Conductors under Downburst Wind

Dr. A. Elatar – Postdoctoral Fellow, supervisors: Dr. G. Bitsuamlak and Dr. H. Hangan
Wind Load Mitigation on Roof Top Solar Panel Arrays

Dr. Bodhisatta Hajra – Postdoctoral Fellow, supervisor: Dr. G. Bitsuamlak
Large scale testing for wind

J. Chowdhury – PhD Candidate, supervisor: Dr. H. Hangan
Wind Effects on Ground Mounted Solar Panels

D. Romanic – PhD Candidate, supervisor: Dr. H. Hangan
Wind Resource Assessment in Complex Urban Environments

D. Parvu – PhD Student, supervisor: Dr. H. Hangan
Downburst Characterization in the WindEEE Facility

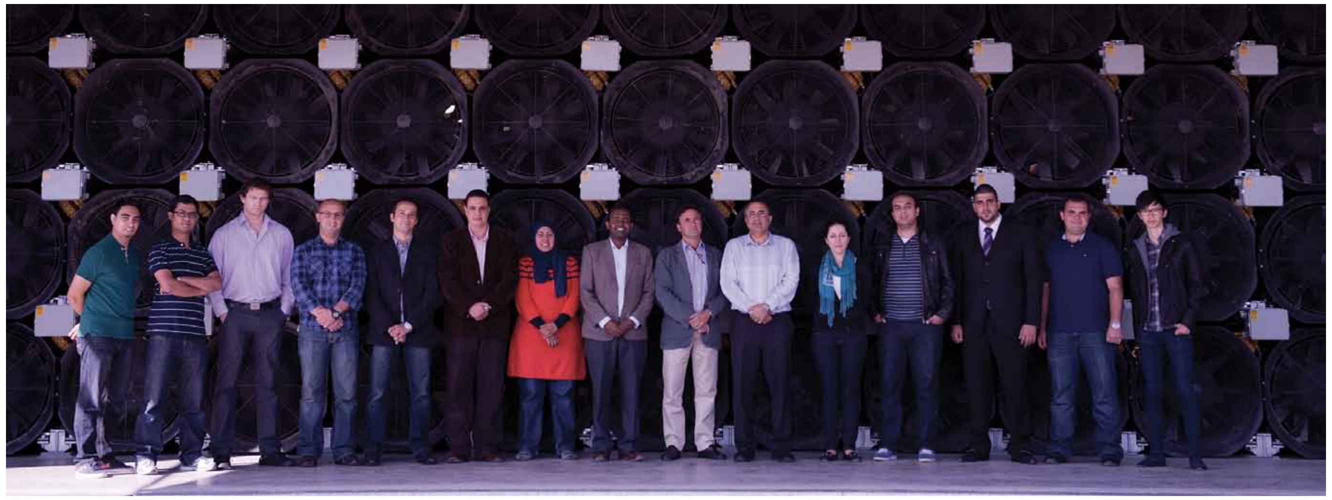
Z. Mohammadvali Samani – MSc Student, supervisor: Dr. H. Hangan
Wind Loading on Full Scale Solar Panels

R. Kilpatrik – MSc Student, supervisors: Dr. K. Siddiqui and Dr. H. Hangan
Flow Structures over Bolund Hill

A. Elnajar – PhD Candidate, supervisor: Dr. A. El Damatty
Effect of Topography on Tornado Response of Transmission Lines

M. Hamada – PhD Candidate, supervisor: Dr. A. El Damatty
Testing and Behaviour of Transmission Lines Under High Intensity Wind

A. Elshaer – PhD Candidate, supervisors: Dr. A. El Damatty and Dr. G. Bitsuamlak
Resilience and Sustainability of High Rise Buildings



A. Ibrahim – PhD Candidate, supervisor: Dr. A. El Damatty
Behaviour of Reinforced Concrete Transmission Towers under High Intensity Wind

A. Elawady – PhD Candidate, supervisor: Dr. A. El Damatty
Development of Design Procedure for Transmission Lines to Resist Downbursts

M. Kahsay – PhD Candidate, supervisors: Dr. G. Bitsuamlak and Dr. F. Tariku
Building enclosures with added sustainability functionality

A. Awol – PhD Candidate, supervisors: Dr. G. Bitsuamlak and Dr. F. Tariku
Sustainable building engineering: Effects of openings on buildings in ventilation, exfiltration and infiltration

T. Hunegn – PhD Candidate, supervisor: Dr. G. Bitsuamlak
Aerodynamic and dynamic optimization of horizontal (bridge) structures

Z. Nasir – PhD Candidate, supervisor: Dr. G. Bitsuamlak
Numerical modeling of tornadic flows

Facilities

WindEEE Dome

The Wind Engineering, Energy and Environment (WindEEE) Dome, see Hangan (2014), is the world's first 3D wind chamber, consisting of a hexagonal test area 25m in diameter and an outer return dome 40m in diameter. Mounted on the peripheral walls and on top of the test chamber are a total of 106 individually controlled fans and 202 louver systems. Additional subsystems, including an active boundary layer floor and "guillotine" allow for further manipulation of the flow. These systems are integrated via a sophisticated control system which allows manipulation of the flow with thousands of degrees of freedom. A pair of 5m diameter turntables, one inside and one outside of the dome, as well as a removable contraction section accommodate a wide variety of test objects and wind speeds.

The WindEEE facility is designed for a LEEDs Silver accreditation and includes office space for industry, researchers, staff and graduate students as well as meeting and conference spaces for collaboration. WindEEE provides working space for approx. 40 people and is part of the Advanced Manufacturing Park (AMP) with supplementary hoteling capabilities at the adjacent Collider Centre.

Testing Capabilities

The WindEEE Dome can accommodate large scale, three-dimensional and time dependent wind testing that no other wind tunnel can handle. WindEEE can be operated as:

1) A three-dimensional testing chamber (hexagonal of 25 meters in diameter and 3.8 meters height) that can produce tornadoes and downbursts as large as 5 meters in diameter and translate these wind systems at 2 m/s over 5 meters inside the chamber. The geometric scale for tornadoes and downbursts is of the order of 1/100 to 1/200 and the velocity scale is of the order of 1/3 to 1/5 of real phenomena. A detail and proper scaling procedure for tornadic flows is presented in Refan et al. (2014). In this capacity WindEEE is used to determine loading of buildings, structures as well as the response of flying devices due to tornadic and downburst winds and compare these loads and responses with the ones resulting from straight flows. Application range from the testing of model scale industrial, municipal, hospital and individual buildings to testing of aeroelastic models of transmission lines or wind turbines or the response the of model airplanes.

2) A multi-fan wind tunnel with a wall (14 meters wide, 3.8 meters high) of 60 fans (4 rows x 15 columns) that can produce large scale atmospheric boundary layers, any type of horizontally and vertically sheared flows with various space and time correlations. In this mode WindEEE can be used to test large scale, prototype or full scale objects to a large variety of wind fields. Applications range from testing of full scale solar panels and small wind turbines, large scale topographic and canopy models, large scale wind turbine components (blades, towers), unmanned flying vehicles, etc.

3) An open jet with the wall of 60 fans running in reverse outside of the dome where a testing platform is available for testing very large components to wind, wind-driven rain and wind-driven snow or other particulate flows. Application range from testing various type of environmental measurement devices, large solar panels or building components and even to the capacity to test in stages a real wind turbine blade.

Equipment

The WindEEE Facility is furnished with a suite of instrumentation and data acquisition systems to facilitate all types of wind related research and testing, including:

- pressure scanning system
- Cobra probes
- 6 DOF force balances
- pollution dispersion system
- high-speed Particle Image Velocimetry (PIV)
- Particle Tracking Velocimetry (PTV)
- mobile LiDAR
- rain and snow rakes
- full-scale monitoring system

An in house CNC router, hot wire cutter and 3D printer can be used to produce models and topography with intricate detail and high accuracy.

Model WindEEE Dome (MWD)

The Model WindEEE Dome (MWD) is a 1:11 scale version of the WindEEE Dome. The MWD was originally used as part of the design validation for the full scale facility and underwent significant flow studies. The MWD has many of the same features as the full scale WindEEE Dome and is able to produce the same flow scenarios.

The model is located on the main Western University campus at the Boundary Layer Wind Tunnel Laboratory. Because of its inexpensive operation and maintenance costs, the MWD will continue to serve as a tool for preliminary test validation/set-up, fundamental tornado research and demonstrations.

Reference

Hangan, H., "The Wind Engineering Energy and Environment (WindEEE) Dome at Western University, Canada", Wind Engineers, JAWE, Vol. 39pp.350

Refan, M.*, Hangan, H., Wurman, J., "Reproducing Tornadoes in Laboratory Using Proper Scaling", J. Wind Eng. And Ind. Aerodynamics, Vol. 135pp.136

Research

1. Wind Engineering

- Tornado wind loading on essential buildings
- Downburst effects on utility transmission lines
- Wind loading on full scale roof mounted solar panels
- Wind effects on ground mounted solar panels
- Numerical simulations of tornadic and downburst flows
- Finite Element Analysis of collapse modes due to wind

2. Wind Energy

- Aerodynamic testing of smart blades
- Aeroelastic testing of model scale wind turbines
- Topography and canopy effects
- Full-scale campaigns

3. Wind Environment

- Wind resource assessment in complex urban environments
- Smart cities and buildings
- Wind-driven rain/snow
- Pollution-dispersion studies
- Effect of complex flows on unmanned flying objects

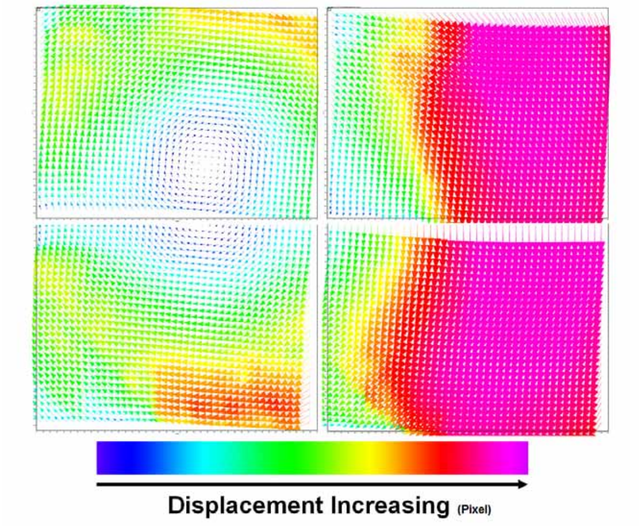
PIV Measurements of Tornado Flows

Canada experiences the second highest number of tornadoes in the world after US. In fact, it is believed that the number of tornado observations/reports is significantly lower than the actual occurrences [3].The tornadic events in Barrie 1985 [4], Edmonton 1987 [5], and southern Ontario 2009 [6] are amongst the most significant and costly tornado events in Canadian history. Ontario has seen a handful of damaging tornadoes in the past few years; the F1 tornado that hit Vaughan area in August 2009 cost $88 million in insured damage while the tornado that hit Leamington area in June 2010 cost $120 million and the F3 rated tornado that hit Goderich, ON in 2011 cost $75 million in insured damage.

Major barriers to evaluate tornado wind loads exist at different levels; there is a scarcity of field data on tornado wind fields within the lower atmospheric boundary layer level creating a gap both in estimating design wind speeds and obtaining target flow characteristics for laboratory simulations and there is a lack of laboratory methods to model tornado interaction with buildings.

Herein, the WindEEE Dome is employed to simulate translating tornado vortices as large as 5m in diameter. The simulated tornado flow field in WindEEE Dome is characterized using flow visualizations methods, surface static pressure measurements and Particle Image Velocimetry (PIV) technique. Four CCD cameras along with a 450 mJ/pulse Nd:YAG laser are employed to perform the PIV measurements at various swirl ratios, Reynolds numbers and heights above the surface. The figure below demonstrates the average horizontal vector maps of the tornado vortex at z=33 cm and for S=35 obtained from the 4-camera setup.

In the next step, the effect of swirl ratio (S) on the core radius (rc), maximum tangential velocity (Vtan) and axial profile of the radial velocity (Vr) will be investigated.



Vector maps showing horizontal velocity field obtained from 4 cameras at 33 cm above the ground and for S=0.35

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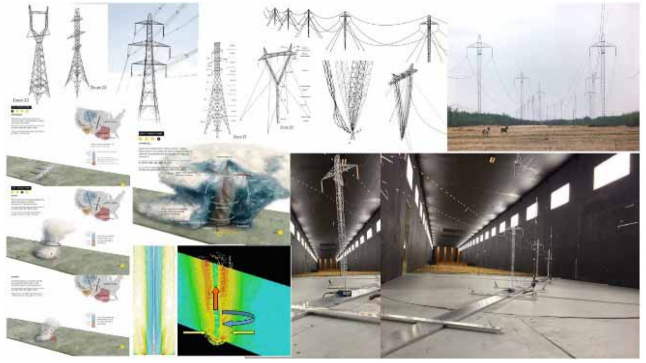
Behavior of Transmission Line Systems under Tornado Wind Loads



This research presents a significant development in the understanding of the structural behaviour of transmission line systems under tornado loading. A comprehensive in-house numerical model that combines the data of computational fluid dynamic (CFD) simulations of tornado wind fields with three dimensional nonlinear structural analysis modelling is developed. The in-house model formulation is extended by including a simulation for members of the lattice towers using three dimensional nonlinear frame elements. By including a failure model, the numerical model is used to gain an insight about the resilience of lattice transmission towers against failures when experiencing an F2 tornado, to describe the failure modes under such events, to assess the effect of different assumptions regarding post yield tension behaviour, and to quantify the effect of inclusion of geometric nonlinearities.

A sophisticated aeroelastic model of a three span transmission line system is designed and tested in the boundary layer wind tunnel test. The results of the test are used to investigate the dynamic response of the transmission line system under boundary layer wind, and to validate the developed numerical model. The model will be tested under HIW at the WindEEE dome. Finally the numerical model is used to develop a set of load configurations simulating the critical effect of F2 tornado on Lattice transmission line structures that can be implemented in the codes of design and can be used by line design engineers.

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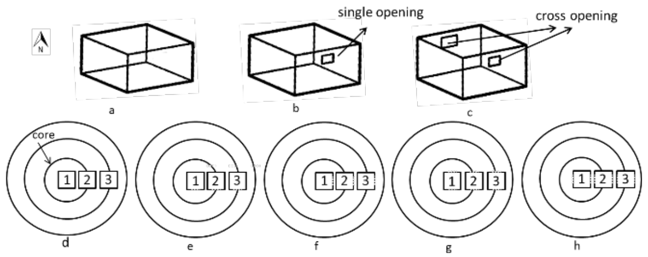
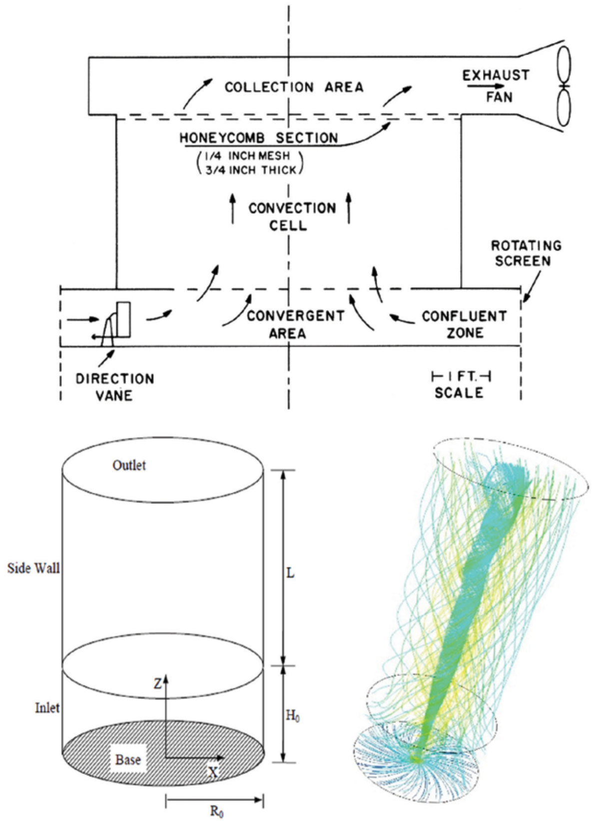
Tornado induced load on a bluff-body with and without openings

Tornado is one of the most violent natural disasters that causes thousands fatalities and millions of property damages every year in North America. For example in 2013 alone there were at least 811 confirmed Tornado that caused 53 lives and about 2.4 billion US dollars in damages. Compared to synoptic flow studies, very limited studies exist for non-synoptic wind. These limited studies have employed either numerical or laboratory experimental approaches to assess flow structure of tornado and its interaction with buildings. The present study further builds on the numerical study of tornadic effects on buildings with (unsealed) and without (sealed) openings located at various locations with respect to the core and by implementing a consistent geometric scale appropriate for tornadic flows.



Study model with various porosity and location with respect to the core of the tornado

The computational domain has a cylindrical shape similar to the actual Purdue tornado simulator. The numerical tornado like vortex will finally be validated in comparison with tornado produced at the WindEEE Dome.



Wards tornado chamber, computational domain and tronado like vortex

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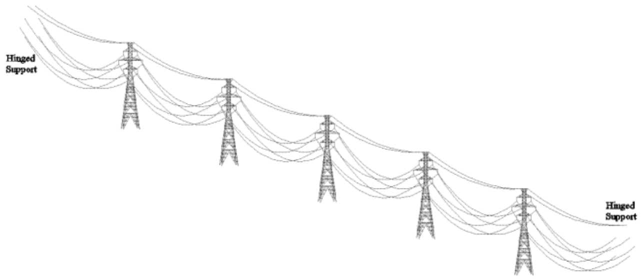
Transmission Lines Behaviour under Tornadoes Wind Loads

Electrical energy plays a vital role in many aspects of daily life. United States and Canada are active zones for tornadoes with approximately 800 to 1,000 tornadoes per year (ASCE 2010). Severe wind events in the form of downbursts and tornadoes are referred to as High Intensity Winds (HIW). Such events are responsible for more than 80% of all weather-related transmission line failures worldwide



Schematic layout of the transmission line system model

Despite this fact, the current codes of practice for transmission line structures do not account for wind loads resulting from tornadoes events. In these codes, the specified design wind loads are based on large scale storms with conventional boundary layer wind profile, which is different than the tornado profile. The forces acting on the structure depend on the location of the storm relative to the structure. Therefore, it is important to identify the tornado and downburst locations that lead to the maximum structural responses. This is challenging for transmission lines, where the wind forces resulting from tornadoes vary along the span of the lengthy conductors and along the height of the towers. Thus, self-supported and guyed aero-elastic tower models will be tested under a simulation of the tornadoes wind in WINDEEE to understand the behavior of both transmission lines systems under the complex wind profiles of the tornadoes.

Finally, the behavior of angle and end lattice transmission towers will be assessed under tornado wind loads. The research proposed in this study will build on the findings, developments and experience gained during the previous research program. The objective is to develop guidelines for designing transmission line structures to resist HIW events and to use these findings in codes of practice.

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Downburst Characterization in the WindEEE Facility

Downbursts are strong ground-level wind systems, originating from a thunderstorm cloud base, directed downwards, which generate short duration high intensity winds on the ground. Several experiments will be carried out to determine the scale dependency and flow dynamics of downbursts in the new WindEEE facility.

A comparison will be carried out between the results obtained at WindEEE and a small scale experiment performed at IMFT (Toulouse) to determine Reynolds number dependence. The focus will be on the experimental study of downbursts by two approaches:

- A small scale experiment at IMFT (Toulouse, France) using an air compressor connected to a tube with the exit shaped as the bell-mouth in WindEEE;

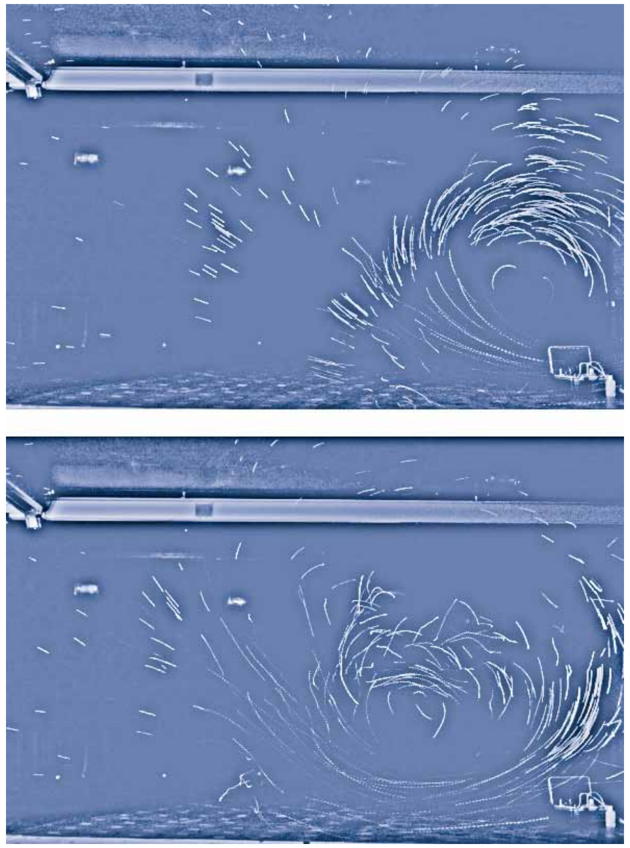
- Another experiment at much larger scale (approximately 300 times larger) at WindEEE;

The experimental study at the WindEEE facility will be split into two experiments.

- Bell-mouth exit flow characterization using a combination of Cobra probes and Pitot tubes placed on a cross beam structure attached to the bell-mouth;

- Characterization of the rest of the downburst flow for two main regions: the center and the extremity of the flow. This will be accomplished by using neutrally-buoyant helium-filled bubbles and a strobe light in order to obtain velocity data (shown in figure);

A set of preliminary tests were done using the strobe/helium bubble method and several photos are presented. The figure shows a sequence of photos taken for the extremity of the downburst flow. Rolling vortex motion can be observed when the flow encounters the impinging surface – in this case the test chamber floor.



Strobe/helium bubble visualization of downburst flow in WindEEE

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Behavior and Design of Transmission Line Structures under Downburst Wind

Electricity outage due to transmission line (TL) failures adversely affects the society from both social and economic point of views. Past reports confirmed that about 80% of the weather related TL failures are attributed to High Intensity Wind (HIW) Events in form of Downbursts and Tornadoes. The current research focuses on the downburst side.

Field evidence of lattice tower failure at cross arms due to downburst event (Manitoba Hydro, 1999)

Typically, TL consists of towers, insulator strings, conductors, and ground wires. The conductors are connected to the tower through the insulators while the ground wires are directly connected to the top of the tower.

Evidently, there is a pressing need to fully evaluate the behavior and response of TL under downbursts. The following milestones are considered in order to address this lack of information:

1. Identify the critical load cases and load profiles of both the tower and the wires considering an intermediate supporting tower.

2. Develop design charts for the wire responses under the critical cases obtained in objective # 1.

3. Assess the behavior of Angle and End transmission towers under different downburst configuration.

4. An experimental program will be conducted at WindEEE dome facility at Western University to verify the proposed design guidelines.

5. Conducting numerical analysis to mitigate the scenario of successive failure of line towers under Downbursts. The results of this analysis will provide the designer with recommendations for strengthening specific towers in the line to avoid this phenomenon, if needed.

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Behavior of Prestressed Concrete Poles under Downbursts and Tornadoes

Transmission line structures plays a vital role in electrical energy transmission, the main components of a transmission line are conductors, insulator strings, ground wires and the tower.

Prestressed concrete transmission towers are widely used due to the low installation and maintenance costs, appropriate delivery time, corrosion resistivity and resistance to insects attacks.

Motivated by the lack of design provisions in current design codes of practice, which focus mainly on the behaviour of the concrete poles under normal wind loading, the main objectives of the current research can be summarized as follows:

1. Develop a numerical model which can be used to analyze both cantilever and guyed prestressed concrete poles considering material and geometrical nonlinear effects under downburst and tornado loadings.

2. Incorporate an optimization technique to achieve the optimum design of both cantilever and guyed prestressed concrete transmission poles.

3. Develop design load cases simulating tornadoes and downbursts to be used in designing various types of prestressed concrete poles.

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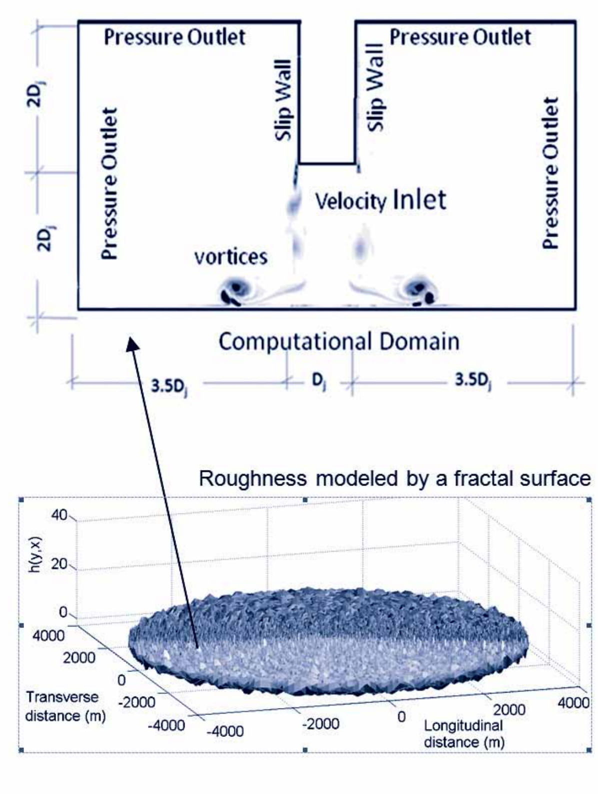
Response of Transmission Line Conductors Under Downburst Wind



Large Eddy Simulation Methodology

Failure of a Transmission Line (TL) can lead to significant economic losses and to negative social consequences resulting from the interruption of power. Downbursts and tornadoes, are believed to be responsible for more than 80% of the weather-related failure of TLs around the world. Previous studies indicated the importance of accounting for the forces transmitted from the conductors to the towers. This research focuses on the response of TL conductors subjected to downburst wind and includes the following studies.

First, an effective numerical technique to analyze transmission line conductors subjected to HIW events is developed. This is followed by a derivation of a simplified closed form solution to estimate the forces transmitted from the conductors to the towers due to downburst winds. Then, dynamic behaviour of TL conductors under downburst and synoptic winds corresponding to open terrain exposure is investigated. In order to account for other terrain exposures, Large Eddy Simulations (LES) of downburst considering various terrain exposures normally encountered by TLs are conducted. Results from the LES are employed to characterize Downburst turbulence is investigate the dynamic behavior of TL conductors.

This research provides an advancement in knowledge about the behavior of transmission lines in general and conductors in particular during downburst events.

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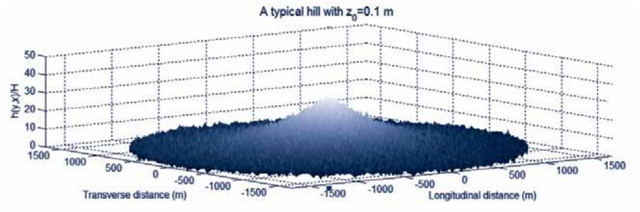
Behavior Of Transmission Line Structures Under Tornadic Wind Field Considering Various Topography Conditions

Downbursts and tornadoes are responsible for majority of weather-related failures of Transmission Line (TL) structures. Failure of a TL typically leads to significant economic losses and to negative social consequences resulting from the power interruption.

This research focuses on investigating the tornadic flow field considering different topographies, encountered by TLs. The considered topographies include cliffs and escarpments with different size and height. Large Eddy Simulation (LES) of tornadoes will be conducted using Ward-type chamber while simulating the topography using the immersed body forces (IBF) method. Resulting tornadic flow field will be decomposed into a mean and a turbulent components, and properties of each component will be characterized. Effect of resulting wind field on TL structures will be investigated.



Topography of a typical cliff with aerodynamic roughness z0=0.1 m

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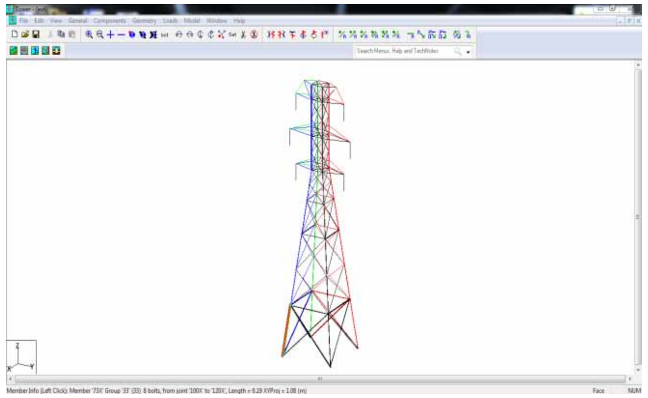
Fluid/Structural Analysis Program Compatible with Commercial Software



Interface of Software "TOWER"

Currently, there is one main program in the market for analyzing and designing transmission lines, named "TOWER". This software, which is used in140 countries around the world, does not account for loads resulting from High Intensity Wind (HIW) events in the form of Tornadoes and Downbursts.

A fluid/Structural analysis computer code, named "HIW", has been developed at Western University to simulate all components of a transmission line system under the effect of HIW events. This code has been enhanced and generalized to be able to simulate different types and shapes of towers. In addition, different Computational Fluid Dynamics (CFD) models, simulating downburst and tornado wind fields, have been incorporated in this program. This program is capable of identifying HIW configurations leading to maximum forces in the tower members and evaluating the external wind loads acting on the tower that correspond to each one of these configurations. These critical loads can be fed into the program "TOWER" and used to design a new line or assess the performance of an existing line.

An important feature has been incorporated in "HIW" that makes its input and output data compatible with the industry-standard "TOWER" program that is widely used in the transmission line industry. Since the software "TOWER" does not account for HIW loads, this compatibility is considered as a valuable feature as it will lead to the development of unique software that is not available elsewhere. This comprehensive software will be utilized to refine transmission line analysis procedure and design criteria and will further enhance the overall transmission line system reliability.

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Wind Load Mitigation On Roof Mounted Solar Panel Arrays

Solar energy is one of the fastest growing renewable energy sector. Photo voltaic solar panels (PV panels) are one of the widely used methods to harvest the solar energy. It is expected that PV solar projects will expand in the coming years due to the decrease in the manufacturing cost of PV panels and improved energy conversion efficiency. On the other hand, these structures (PV panels) are exposed to different climate conditions such as wind, rain and snow. Wind is considered to be design controlling parameter. This is primarily due to the PV panels structure which is vulnerable to different wind induced forces are installed on roofs where the wind loads are usually the largest. Mitigation of the wind load effect on PV panels is a necessity to reduce design wind loads and subsequently use less ballast, making the solar industry more competitive.

The goal of this project is to develop aerodynamic mitigation solutions to reduce the wind load effects on PV panels under different wind conditions. This will be pursued by developing wind load mitigation techniques that can be incorporated with the PV panels design. Mitigating the wind load can be achieved by changing the flow characteristics around the PV panel by using flow deflectors (solid and/or perforated). Different techniques can be tested for this purpose. To determine the proper techniques that can effectively reduce the wind load on PV panels, the forces on the PV panel will be measured for each tested technique under different wind conditions before and after installing the mitigation solution. In addition, the flow behavior around the PV panels will be characterized to have a clear understanding for the effect of each technique on the wind load on the PV panels to layout the applicability range of the solutions. Both numerical and experimental approaches are being pursued in this project.

Full-scale solar array testing at the WindEEE Dome

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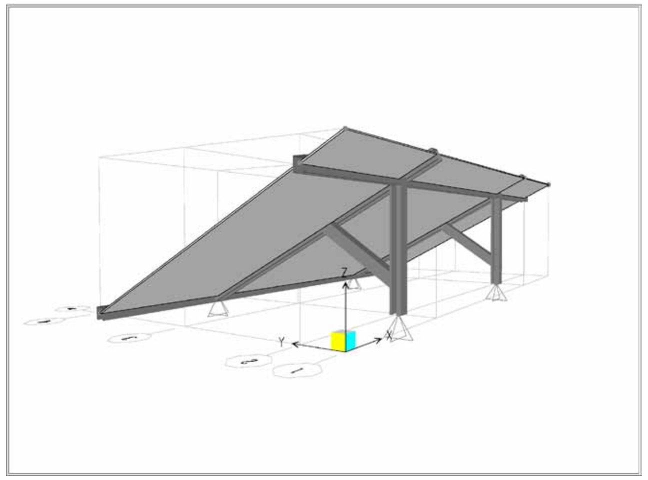
Wind Loading on Full Scale Solar Panel

Solar energy is a renewable and clean source of energy that can be a good replacement for conventional fuel resources. During the past decade, many researchers have attempted to improve the efficiency of solar panels for generating power. Although the application of solar panels is rapidly growing nowadays, the main obstacle in using solar panels in industrial scale is the initial capital. The cost of supporting structure of solar panels is a significant portion of the total cost. Therefore, optimization of this structure is essential in order to reduce the cost of solar panels manufacture.



Structural model of the solar panel with 25° slope

The key factor in optimization of the supporting structure of solar panels is determination of accurate wind loading. This is achieved by simulation of wind profile using the equipment of WindEEE laboratory and applying the wind loading on a full-scale solar panel. Pressure distribution on both surfaces of the solar panel will be measured through 500 pressure taps and then the aerodynamic pressure distribution on the panel is determined. Then, the critical loading can be obtained.

During the experiment, strains of the structural members as well as the reaction forces of the entire structure will be measured by strain gauges and force balances, respectively.

The experimental loading data will be used as an input load for numerical simulation of the supporting structure of solar panels. These critical loadings will be employed for optimization of supporting structure's design.

The structural model will be then simulated and calibrated with forces and strains obtained from the experiments. Once the calibration is performed, the model would be employed for all other loading conditions, and different configurations of solar panel. The results of experimental and numerical analysis will be used for optimization of supporting structure of solar panels. This leads to reduce the cost of solar panels manufacture.

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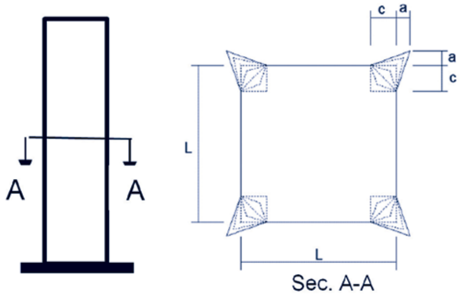
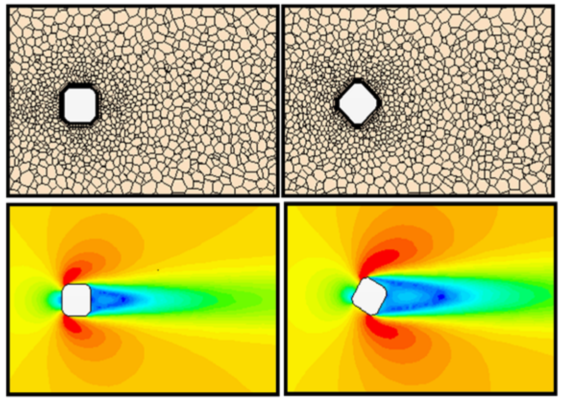
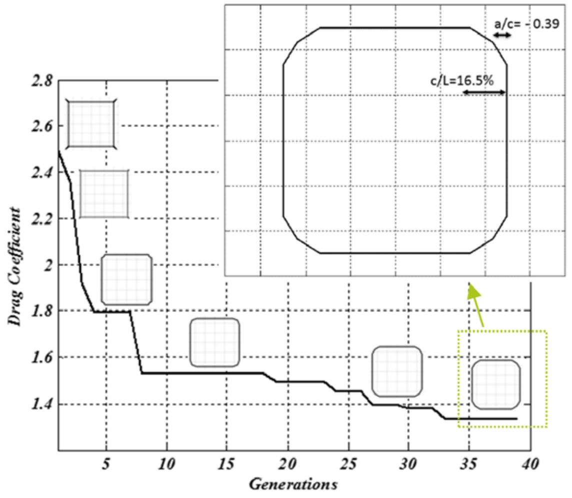
Aerodynamic Optimization of Tall Buildings

With the development of new building materials and construction techniques, the new generation of buildings is becoming more flexible and of lower damping and lighter weight. Resulting in sensitive structures to the dynamic effects of wind characterized by excessive vibration. These motions will develop high values of base straining actions, whose mitigation can increase the cost of the structure. Furthermore, keeping the motions of the towers within comfortable limits is required in addition to other strength requirements.



Aerodynamic modification on the external shape of the building has become an important aspect of tall building design process to mitigate wind effects. Examples include higher level openings, tapering, twisting the structure around its vertical axis or modifying the building corner details can be beneficial. In this study, a reliable aerodynamic optimization framework is being developed by combining genetic algorithm, geometry modeling using the B-spline functions, and Computational Fluid Dynamics solver to predict the optimum shape for super tall buildings in order to reduce their straining actions, vibrations, and subsequently their cost. The numerically recommended solution will be validated at the WindEEE Dome, whose large scale capability is beneficial considering some of aerodynamic recommendation constitute fine details at the corner of the study buildings.





Aerodynamic modifications for drag

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Aerodynamically Efficient Bridge Deck Sections

Long-span bridges are wind sensitive by the virtue of which their structural response resulting from interactions with wind prevails over other environmental loads. The vibrations resulting from bridge-wind interactions can be annoying as in the case of Storebaelt Bridge in Sweden and Rio - Niteroi Bridge in Brazil, or can lead to catastrophic failure as in the case of the first Tacoma Narrows Bridge. To mitigate such unfavorable effects of the interaction, shape modifications of bridge decks such as partial streamlining, venting, and provision of appendages such as guide vanes can be implemented successfully.

Shape modifications to existing long-span bridges as in the case of White Bronx Bridge or development of aerodynamically efficient bridges as in the case of the proposed Messina Straight Bridge were carried out through the traditional experimental based “cut and try” procedure. This procedure is believed to be both time consuming and costly as compared to computational based approaches. Hence the objective of this research project is to present a computational procedure to automate the optimal shape modification process for long-span bridge decks. The technique comprises of computational fluid dynamics (CFD) for estimating aerodynamic forces and numerical optimization tools to automate the shape modification process. The optimal deck shape determined numerically will be validated through large scale testing at WindEEE Dome.

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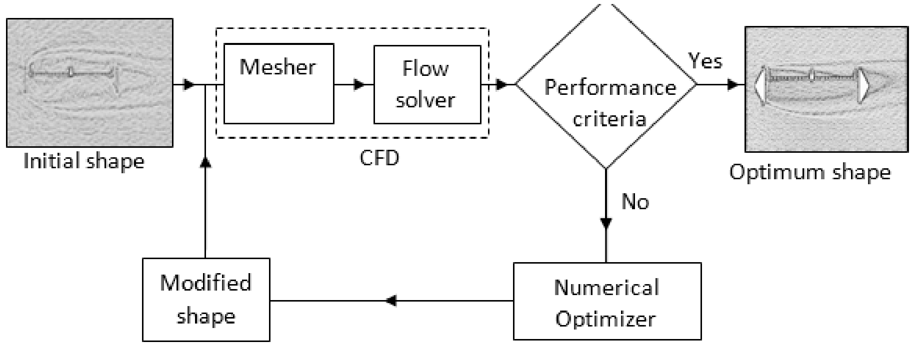


Flow chart for computational aerodynamic shape optimization of long-span bridge decks

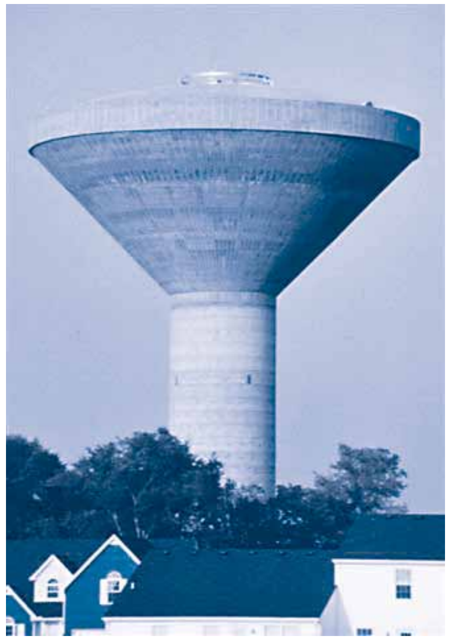
Behavior of Steel Conical Tanks Under Seismic and Wind Loading

Steel conical tanks are widely used for liquid storage around the world. A number of those tanks collapsed in the last decades at different places as a result of instability of the steel shells. Despite being widely used, no specific design procedure is available for conical tanks either under static or dynamic conditions.

In the first part of this study, the base shear and vertical force capacities of steel conical tanks under hydrodynamic pressure due to horizontal and vertical excitations are obtained using non-linear static analysis. The obtained capacities are compared to the seismic demand obtained through previously developed mechanical model found in literature in order to assess the design of this kind of tanks under hydrostatic pressure.

Then the effect of the base rocking motion on the seismic behaviour of conical shaped steel tanks is studied and a mechanical analog taking the rocking motion into consideration is developed. The mechanical model takes the flexibility of the tank walls into consideration as well the hydrodynamic pressure acting on the tank base.

Finally, the steel conical tanks are assessed under the effect of wind loading where the wind pressure distribution over the tank walls is obtained using CFD simulations that is been validated using wind tunnel testing studies for conical shaped tanks found in literature.


Example of a pure conical tank

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Structural Analysis Software for High Intensity Wind Effects on Transmission

An extensive research program studying numerically and experimentally the behaviour of transmission line structures under tornado and downburst wind effects has been initiated by a number of investigators at Western University in collaboration with Hydro One Ontario. The investigators at Western, succeeded in matching Hydro One funding from NSERC and OCE with a total project budget exceeding $1.2M.

The main objective of this research is to develop and validate a computer code to predict the critical loads acting on transmission line structures due to High Intensity Winds (HIW), in the form of tornadoes and downbursts, using state-of-the-art numerical tools.

There is a clear lack of tools, in the form of code specifications or computer software, for the analysis, performance assessment and design of transmission lines to resist HIW events. This new software will be invaluable for Hydro One, in particular, as well as for other utility companies in Canada and abroad.

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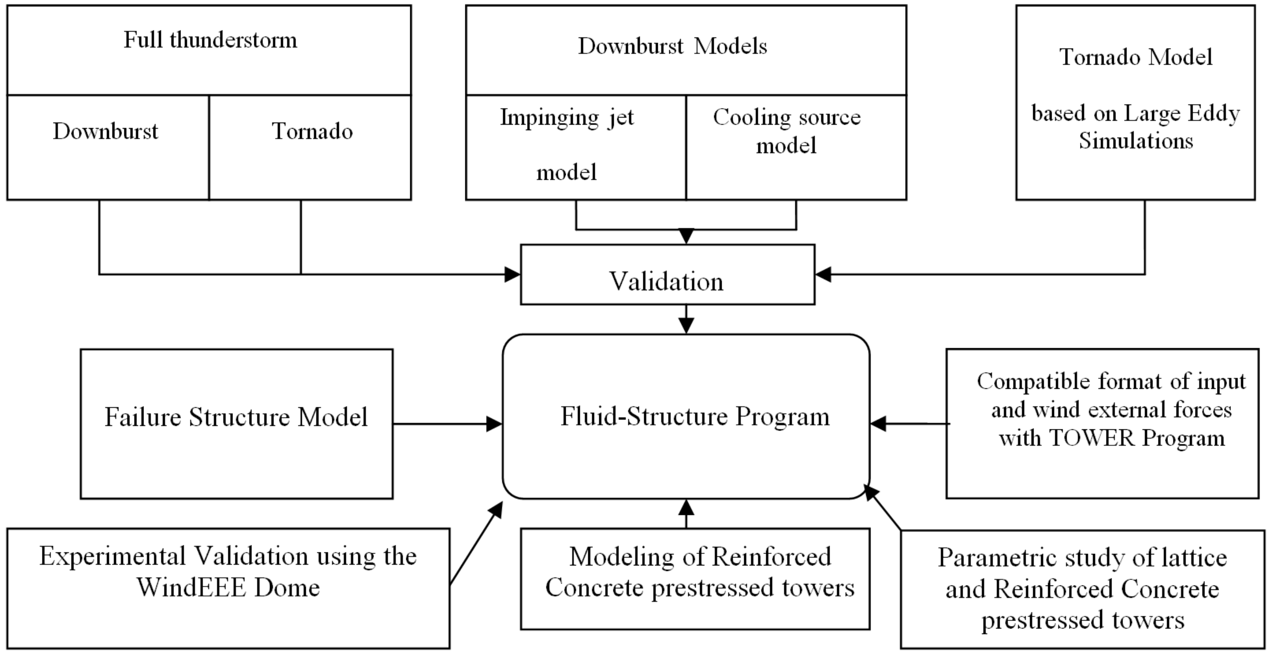

Flow Chart of the Project

Wind Resource Assessment in Complex Urban Environments

The urban wind assessment study is performed on a city block in south of the city of Toronto, ON, Canada (2015 Pan American Games Athletes' Village). The CFD simulations are carried out using the CD-Adapco StarCCM+ software. The governing equations for this problem are three-dimensional steady Reynolds averaged Navier-Stokes equations without heat transfer. Shear stress transport k-ω turbulence model adjusted for a transitional flow is used. The annual wind data for the site location are obtained from the Canadian Wind Energy Atlas.

It is shown that, considering only 90° and 240° wind directions, the extractable wind energy to the required energy for the selected blocks ranges from 1% - 4%, which is much less than the maximum extractable wind energy (3.5% - 12.5%).

The large gap between the energy production and maximum extractable energy is mainly due to the lack of wind turbines specifically designed for urban areas. The best solution will be designing a single wind turbine that operates as a drag based turbine in low wind speeds and changes into a lift based design in higher wind speeds.

In the next step, the CFD model will be coupled with a mesoscale meteorological model. This will further increase the accuracy of the wind resource assessment in urban areas.

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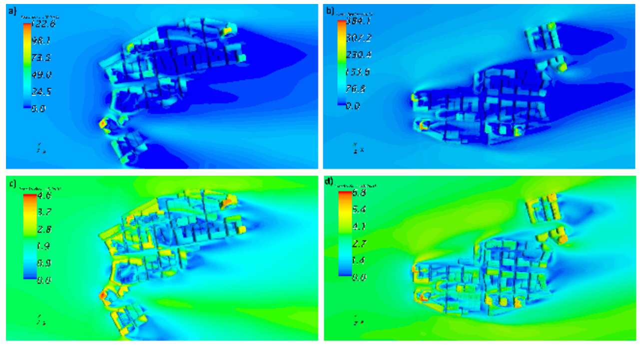
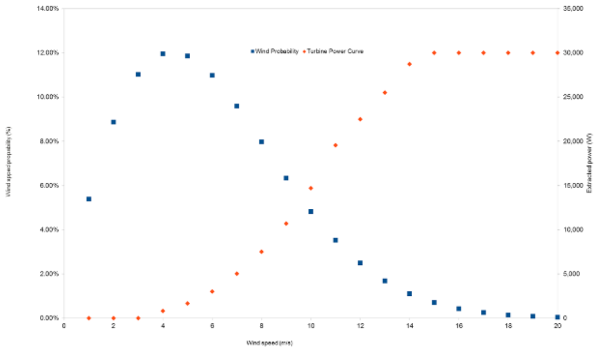
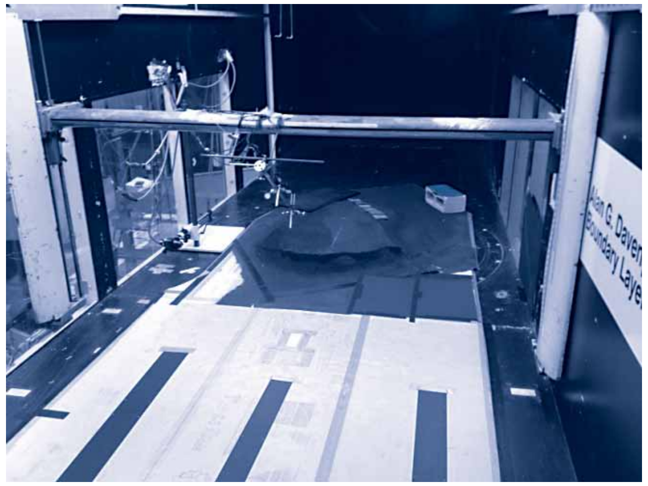


Mean power density (upper panels) and wind speed (lower panels) 8m above the buildings and ground for 90° direction (left panels) and 240° direction (right panels). Flow direction is along the x-axis.

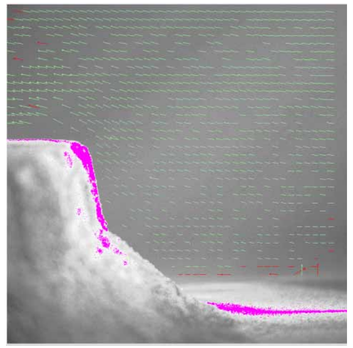


Comparison of the wind probability distribution function and the power curve for generic 30 kW wind turbine used in this study.

Flow Structures over Bolund Hill



Measurement set-up in the wind tunnel



Horizontal vector map of the flow upstream of the Bolund

Bolund hill, a small peninsula located near Copenhagen, Denmark, is characterized by its steep cliff face and long flat section. This site has to date gained considerable attention from wind energy researchers, as this type of topography, at larger scales, is typically well-suited for placement of wind turbines.

Maximizing the efficiency and electricity generation potential from wind turbines situated near complex topography will require improved characterization of the wind speed, direction, and turbulence intensity in the area of interest.

Particle image velocimetry (PIV), along with hotwire and Cobra Probe measurements, are used to observe and measure the air flow over the hill at many different positions. This data will be compared to full-scale data available from tests completed at the Bolund site, in collaboration with researchers at Technical University of Denmark (DTU).

The largest-scale wind tunnel testing of Bolund hill published to date is at 1:115 scale, while current tests at the UWO Boundary Layer Wind Tunnel are being done using a 1:100 scale model. The larger size of the WindEEE facility will permit future models of the Bolund hill to be created at 1:50 scale or larger, thus increasing the resolution of the flow structures. Planned studies include a Reynolds number dependency test, as well as examination of different wind directions.

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The Causes and Consequences of Stakeholder Resistance to Wind Farm Development in Ontario

This research project studies the impact, and causes, of stakeholder resistance towards wind farms on project development and regulatory permitting processes. Stakeholders, including local community activists, environmental NGOs, municipalities, labour unions, and others, have in some instances resisted the development of wind farm proposals in Ontario, citing adverse impacts on the natural environment, human health, and property values. There is little understanding, however, of whether stakeholder organization and resistance is actually effective in preventing, delaying or modifying wind farm project development through the regulatory permitting process. Further, little research has systematically examined the factors that generate high levels of resistance to wind farms while other projects receive local community acceptance.

In this research project we examine these issues empirically, assembling micro-level data on regulatory permits awarded to every wind farm operating or in development in Ontario since 2003. Permits and licenses include those from the Ontario Power Authority, the Independent Electricity System Operator, the Ministry of Environment, and the Ontario Energy Board. By tracking the dates of permits, as well as publicly announced expected operation dates, measures of project duration and delay can be created.

We also develop gauges of stakeholder resistance to wind farms, such as formal regulatory appeals, municipal council anti-wind resolutions, legal appeals, and public protests by anti-wind groups. The combined database will permit a detailed analysis of why some wind farms meet significant barriers to achieving 'social license', an issue of concern for a broad range of firms in the energy sector.

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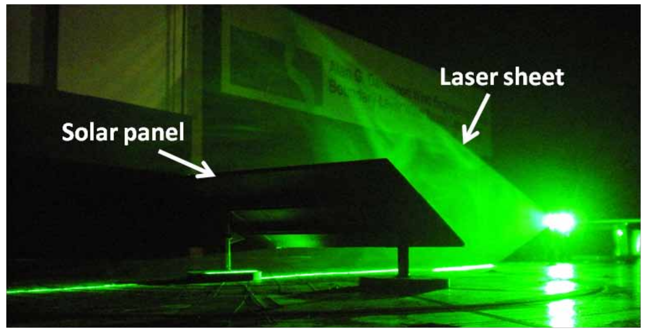
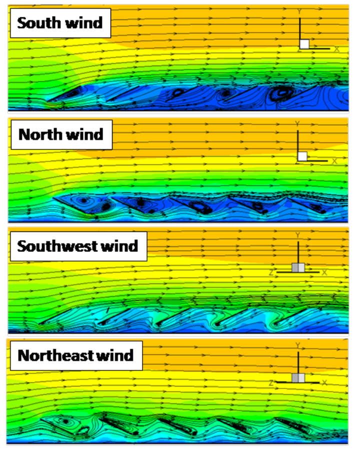
Wind Effects on Ground Mounted Solar Panels



Setup at the wind tunnel during PIV experiment



CFD simulation of wind flow around south facing array of solar panels

Optimizing PV panel support structures to withstand aerodynamic forces is one of the challenges experienced by the solar panel manufacturer and installer. North American building standards do not provide any information regarding minimum design wind load for solar panel arrays, either ground mounted or roof mounted.

CFD simulations are carried out to evaluate wind loads on a ground mounted stand-alone solar panel system as well as an array of solar panels with application to solar farms. Wind flow characteristics around the solar panel are analyzed to better understand the mechanism behind wind loads.

Besides CFD, wind tunnel experiments are also performed to measure surface pressure and wind velocity (using Particle Image Velocimetry, PIV) for ground mounted solar panels. Results show that for a south facing stand-alone solar panel, northern wind produces the maximum uplift and cornering winds cause the maximum overturning moment. For solar farms, the first leading row experiences the maximum wind load for four wind directions (South, North, Southwest and Northeast wind for South facing panels) considered in the present research. Also, due to the sheltering effect from the leading row, mean wind load (drag and lift) is the minimum around the second or third row; but the wind load gradually increases towards the downstream rows. Unlike drag and lift, the overturning moment is high under cornering winds for all rows of panels.

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Investigation of Natural Convection during Solid-Liquid Phase Change Process with Applications in Thermal Energy Storage

Thermal storage mediums are gaining significant attention due to their increasing importance in building sustainability and the effective utilization of solar thermal energy in various applications. The heat storage capacity can be increased substantially by using materials that change phase during the heat addition and heat removal states, termed as the Phase Change Materials (PCMs). One of the major challenges with the designing of PCM thermal storage is the effective heat transfer to and from the PCM volume, which influences the efficiency and performance of the storage medium. The specific focus of this research project is to conduct a detailed investigation of the heat transfer process in PCM thermal storage. The experiments were conducted using wax with tracer particles in a small chamber.

The research work includes the characterization of the interface motion and the flow behaviour of the melted PCM, and their relation to the heat fluxes and the orientation of the heat source. The future steps include the consideration of multiple heat sources in the storage chamber and the investigation of the role of thermal conductive enhancers (TCE), especially the nanoparticles, in the heat transfer process.

The knowledge gained from these experiments will be used to propose an optimal thermal storage design with higher storage capacity per unit volume and efficient heat exchange between the storage medium and working fluids.

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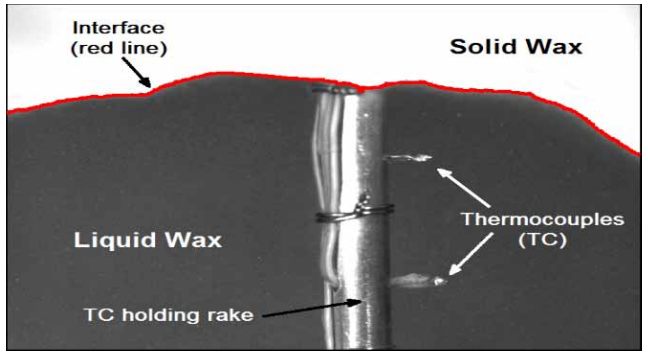
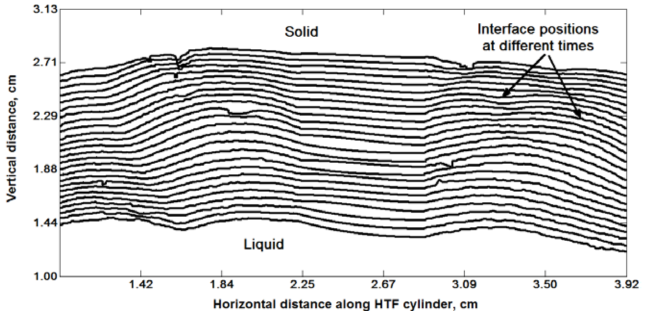
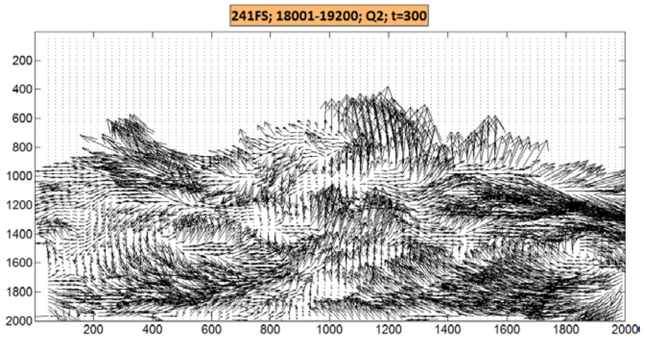


The PCM storage enclosure with the interface shown in red line during the melting process.

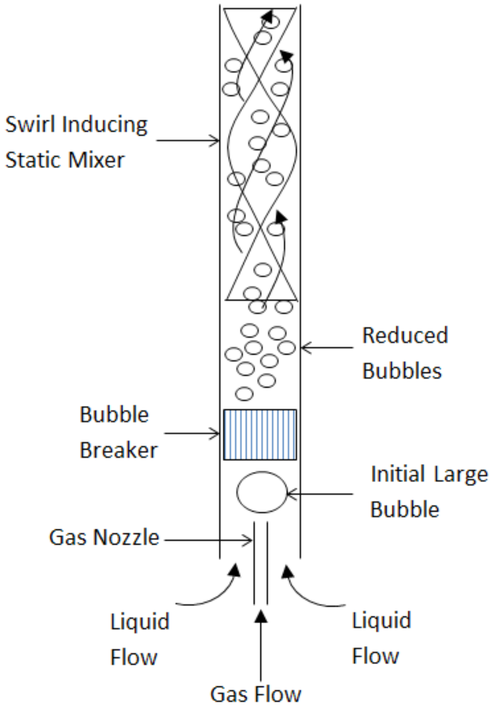


Positions of interfaces at different times during the melting process for a heat flux of 19,400 W/m^2.



Velocity fields in molten PCM after 18 min of melting.

Heat and Mass Transfer Enhancement in Vertical Tubular Absorbers



Schematic drawing of the proposed absorber design

Solar heat absorption refrigeration systems can be used in residential applications to reduce peak summer electricity loads due to building cooling. The efficiency and overall size of these systems are dependent on the absorber component. This project is focused on the investigation of effective techniques to enhance the heat and mass transfer in a vertical tubular absorber for a more compact refrigeration system.

It has been shown that the use of a mesh bubble breaker in two phase vertical co-flows can reduce the bubble size resulting in higher surface-to-volume ratio allowing higher mass transfer rates. Convective heat transfer can be increased with the use of passive swirl devices in pipe flow. These devices can also increase the mass transfer rates in two phase flow. By combining a bubble breaker with a static mixing device (as shown in the schematic) a more efficient absorber can be produced.

Bubble breaker shapes and size, static mixer shapes and gas and liquid flow rates will be varied to determine optimal combinations of the enhancement devices.

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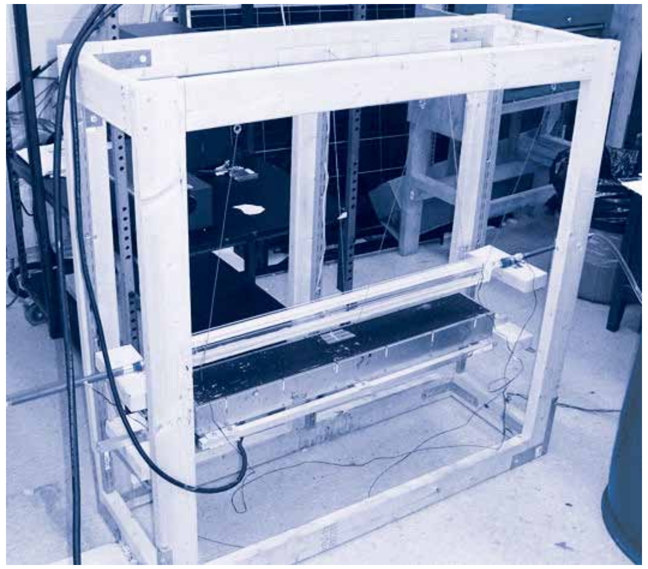
Investigation of Mean And Turbulent Flow Behavior of Nano-Fluids

One of the simplest methods to transport heat-energy from one place to another is by pumping a heated fluid along the required route. This method of heat-transfer is used in applications such as refrigeration, solar water heaters and nuclear power plants. Seeding any heat-transfer fluid with thermally conductive nanoparticles (1-100 nanometers) provides a more efficient heating system due to an increase in the heat-transfer properties of the fluid.

In the past decade these fluid/nanoparticle colloids, called nanofluids, have garnished great interest in heat-transfer applications. Experimental investigations have shown that adding as little as 4% metal-oxide nanoparticles (by volume) increases the solution's thermal conductivity by up to about 135% compared to that of the base fluid.

Maxwells continuous-medium model, dated over 100 years ago, provides an accurate prediction to the heat-transfer properties of fluids seeded with macroparticles (>1 micrometer). When the diameter of the thermally conductive particles decrease to the nano-scale, the relatively comparable mass of the water molecules tend to push the nanoparticles around. This leads to an additional micro-convective heat-transfer effect in the nanofluid, allowing them to retain heat faster. A general quantitative prediction of this micro-convective effect has not yet been found.

The present research is focused on the investigation of the mean and turbulent flow behavior of nanofluids in a forced convection system by using Particle Image Velocimetry (PIV) technique, along with the estimation of the heat transfer rate. This research will aid in the formulation of a predictable mechanism to be quantitatively utilized for the heat-transfer properties of a nanofluid. Ultimately, this formalism will allow the engineering of a heat-transfer fluid for maximal efficiency in a heating system.



Experimental apparatus

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Conferences

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Bashar M, Siddiqui K. 2014. Investigation of the melting process in a phase-change material. CSME International Congress, Toronto, June 1-4, 2014.

Jobehdar MH, Gadallah AH, Siddiqui K, Chishty WA. 2014. Investigation of internal and external flow in an effervescent atomizer. CSME International Congress, Toronto, June 1-4, 2014.

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Jobehdar MH, Gadallah AH, Siddiqui K, Chishty WA. 2013. Investigation of the bubble formation in liquid cross-flow using a novel nozzle design. ASME 2013 Fluids Engineering Summer Conference, Incline Village, Nevada, July 7-11, 2013.

Gadallah A, Siddiqui K. 2013. A novel nozzle design for reducing bubble size generated in stagnant liquid. ASME 2013 Fluids Engineering Summer Conference, Incline Village, Nevada, July 7-11, 2013.

Elatar A, Siddiqui K. 2013. Three dimensional flow structure during low Reynolds number mixed convection. 24th Canadian Congress of Applied Mechanics (CANCAM), Saskatoon, June 2-6, 2013.

Gadallah A, Siddiqui K. 2013. An innovative nozzle design for reducing bubble size generated in stagnant liquid under constant flow conditions. 24th Canadian Congress of Applied Mechanics (CANCAM), Saskatoon, June 2-6, 2013.

Siddiqui K, Hangan H, Bitsuamlak G, Mann J, Berg J, Refan M, Jubayer C, Kilpatrick R, Romanic D, Lange J. 2014. Energy-related research at the WindEEE Research Institute. 1000 Islands Energy Research Forum, University of Ottawa, October 23-25, 2014.

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Ramadan A, Siddiqui K, El Naggar H. 2013. Design improvement of the ground loop in a geo-source heat pump system. 1000 Islands Energy Research Forum, Queens University, June 13-15, 2013.

Siddiqui K. 2013. WindEEE research facility at the Western University. 1000 Islands Energy Research Forum, Queens University, June 13-15, 2013.

Grants

CFI / $ 3,635,891 / 2014-2019
WindEEE Dome
Hangan

CFI and ORF / $ 31,994,754 / 2009 – 2014
WindEEE Dome
Hangan, others

NSERC / $ 874,296 / 2013-2016
Development of Software for Transmission Line Structures under High Wind Loads
El Damaty, Bitsuamlak, Savory, Hangan

NSERC / $ 110,000 / 2012-2016
Investigation of High Reynolds Shear and Vortex Flow with Application to Wind Engineering, Energy and Environment
Hangan

Tokyo Polytechnic University / $ 7,050 / 2014-2015
Comparison of Tornadic Flow Characteristics Obtained with Experimental Facilities
Hangan

Joint Ontario Center of Excellence and NSERC Engage program / $100,000 / 2014-2018
Aerodynamic mitigation of wind load on solar panel array
Bitsuamlak

Ontario Early Researcher Award, Ontario Center of Excellence / $190,000 / 2014-2018
Multi-scale experimental and computer modeling of wind effects on the built-environment
Bitsuamlak

Canada Research Chair / $ 500,000 / 2012-2016
Wind engineering for resilient & sustainable built environment of the 21st century
Bitsuamlak

Canada Foundation for Innovation Leaders Opportunity Fund for research infrastructure / $ 624,506 / 2013-2013
Large-scale Experimental and Computational Infrastructure for Assessing Wind Effects on the Built Environment
Bitsuamlak

Southern Ontario Smart Computing Innovation Platform / $135,000 / 2012-2013
Weather projections for smart cities, IBM + SOSCIP
Bitsuamlak

NSERC Discovery Grant / $ 130,000 / 2012-2013
High intensity wind load evaluation and mitigation for buildings
Bitsuamlak

OCE/Hassco Industry/Connect Canada / $ 31,000 / 2014-2015
Biomass Processing Technology for Production of Green Power and Value-Added Products
Gomaa, El Damatty

NSERC Engage Grant / $ 25,000 / 2014-2015
Estimation and mitigation of vibrations in reinforced concrete solid slabs
El Damatty

CEATI International / $ 40,000 / 2012-2014
Application Guide for Wind Speed-up Factors CEATI
Bitsuamlak, El Damaty, Savory

CEATI International / $ 69,500 / 2013-2014
Dynamic Response of Transmission Lines Under Wind
El Dammaty, Savory, Bitsuamlak, Hangan

Hydro One / Ontario Centre of Excellence/ NSERC- CRD Grant / $ 838,000 / 2012-2016
Development of Software for Analysis of Transmission Towers under High Intensity Wind Loads
El Damatty, Bitsuamlak, Savory, Hangan

NSERC Discovery Grant / $ 120,000 / 2010-2015
Behaviour and Design Procedures of Transmission Towers Under High Intensity Wind Loads
El Damatty

NRC / $ 9,950 / 2014
Development of an air-fuel control system for Effervescent Atomization Fuel Injector
Siddqui

MITACS Accelerate Internships / $ 30,000 / 2013
Study of potential technologies for net-zero housing
Siddiqui, Bashar, Jobehdar

NSERC (Discovery Grant) / $ 130,000 / 2013-2018
Investigation of Interfacial Thermofluid Processes
Siddiqui

Hydro One / $ 20,000 / 2013
Feasibility study for an Adiabatic (or near-adiabatic) Compressed Air Energy Storage
Schainker, Siddiqui, Dadash Zadeh

C4 iPOP / $ 10,000 / 2013-2013
Novel solar thermal receiver
Siddiqui

CFI / $ 60,317 / 2012-2017
Infrastructure operating fund
Siddiqui

Federal Economic Development Agency (FedDev) / $ 100,000 / 2012-2013
Optimization of Concentrated Solar Power Components and System
Siddiqui

UWO (WIF) / $ 48,850 / 2012-2013
Smart and cost-effective dual-axis solar tracking and load compensator
Siddiqui

Patents

Hassan H, Siddiqui K. 2013. Receiver for use with parabolic solar concentrator. US Provisional Patent application #1018P012US01.

Events

WindEEE Scientific Symposium

Over 90 wind experts from 4 continents, 6 countries and 32 institutions around the world attended a research symposium, public lecture and tour of Western's new WindEEE Dome. The focus of the symposium was to bring together world leaders in wind research to share ideas and debate new trends in the areas of wind engineering, energy and the environment (the three E's in WindEEE).

Wind and Turbulence

Chairs: Horia Hangan & Gregory Kopp

Lord Julian Hunt, Emeritus Professor of Climate Modelling and Honorary Professor of Mathematics (University College, London) and Fellow of Trinity College, Cambridge, UK
"Turbulence Structure and Wind Loads"

Kishor Mehta, Program Director, Hazard Mitigation & Disasters, National Science Foundation, Arlington, Virginia, USA
"Hazard Mitigation and Wind Engineering : Paradigm Shift"

Wind Engineering Innovation

Chairs: Giovanni Solari & Girma Bitsuamlak

Ahsan Kareem, Robert M. Moran Professor of Engineering, University of Notre Dame, Indiana, USA (1st Alan Davenport Medal Recipient)
"Changing Dynamic of Wind Loads: From Uniform Flows to Gust Fronts"

Chris Letchford, Professor & Department Head, Civil and Environmental Engineering, Rensselaer Polytechnic Institute, New York, USA
"Innovative Physical Modeling for Wind Engineering"

Girma Bitsuamlak, Associate Professor, Canada Research Chair in Wind Engineering Tier II, Civil and Environmental Engineering, Western University, London, Canada
"Multi-scale Experimental Modeling of Wind Effects on the Built-Environment"

Acir Mércio Loredo-Souza, Professor of Engineering and Director, Laboratório de Aerodinâmica das Construções, Universidade Federal do Rio Grande do Sul, Porto Alegre,Brazil
"Thunderstorm Winds and Complex Terrains: Challenges for the Brazilian Engineering and the Innovative Potential of WindEEE"

Wind Energy Innovation

Chairs: Rupp Carriveau & Kamran Siddiqui

Jonathan Naughton, Director, Wind Energy Research Center (WERC) & Professor Mechanical Engineering, University of Wyoming, Laramie, Wyoming, USA
"A Roadmap for Validation and Verification Experiments for Wind Energy"

Jakob Mann, Professor of Wind Engineering and Atmospheric Turbulence, DTU Wind Energy Department, RisØ Campus, Danish Technical University, Denmark
"Challenges for Wind Energy"

Guy Holburn, Director, Ivey Energy Policy and Management Centre, Western University, London, Canada
"Public Policy for Wind Energy in Ontario"

Christian Masson, Professor, Mechanical Engineering Department, École de technologie supérieure, Montreal, Canada
"Wake Analysis Using AD/LES"

Wind Environment Innovation

Chairs: Andrew Pollard & Craig Miller

Rebecca Barthelmie, Professor, Atmospheric Science and Sustainability, Indiana University, USA
"Measuring Wind and Turbulence in 3D"

Karen Kosiba, Atmospheric Research Scientist, Centre for Severe Weather Research, Boulder, Colorado, USA
"The Low-Level Wind Structure of Tornadoes and Hurricanes"

David Sills, Severe Weather Scientist, Cloud Physics and Severe Weather Research, Environment Canada, Toronto, Canada
"A Fresh Spin on Tornado Occurrence and Wind Damage Rating in Canada"

Industry Driven Opportunities

Chairs: José Terres-Nicoli & Horia Hangan

Hosam Ali, Director, Structural Hazards and Response Research, FM Global, Norwood, Massachusetts, USA
“Engineering-Based Natural Hazards Loss Prevention”

Dariush Faghani, Senior Analyst-Energy Policies and Strategy, GL Garrad Hassan Canada Ltd., Montreal, Canada
“Industry Driven Innovations in Wind Energy”

Jon Galsworthy, General Manager & Principal, Rowan Williams Davies and Irwin Inc. (RWDI), Guelph, Canada
“Potential Applications of WindEEE Dome to the Wind Engineering of Tall Buildings and Structures”

Suresh Santanam, Deputy Executive Director, Syracuse Center of Excellence in Environmental and Energy Systems, Syracuse, New York, USA
“US-Canada Cross Border Research Collaborations and GLSEC”

Public Lecture

Following the research symposium, guests and the general public attended a lecture by Lord Julian Hunt, Fellow of Trinity College, Cambridge, UK and Honorary Professor in the Department of Applied Mathematics and Theoretical Physics, University of Cambridge. Hunt presented his ideas regarding the trends in the area of meteorology, climate change and wind engineering. Hunt’s presentation covered his work in the area of climate modelling and climate change in the UK. In his closing remarks, Hunt told the audience he believes in order to address climate change, we need to seek more public understanding, apply more practical measures and enforce more policies. He challenged the audience to adapt and design local, regional and global environments while collaborating more with industry and insurance agencies.

WindEEE in the Community

In big picture issues such as climate change and energy production as well as local issues like air and water quality, engineers and scientists have a valuable role to play in serving the interest of society. We believe in the importance of inspiring the next generation of environmental leaders, who will be called to solve increasingly complex challenges in a resource constrained world.

In 2014, WindEEE partnered with TD Bank’s TD Friends of the Environment Foundation to develop the “Winds of Change” community engagement program. Focused on students in grades 8-12, the program allows students a behind the scenes look at a state of the art research facility, while providing some insight into possible careers in wind energy and wind engineering.

The program was designed as a series of classroom visits to the WindEEE site. At each session, the students go on a guided tour of the WindEEE facility, including a live demonstration of the test chamber where possible. Following this, the students are given a brief lesson on the basics of wind turbine operation, after which they work in teams to build their own model wind turbines and measure the amount of electricity produced. Students are encouraged to tweak their designs to generate more power, similar to the real-world engineering design process.

To date, two sessions have taken place, with another 3 scheduled and an additional 5 sessions planned for the spring to bring the total number of participants to 10 classes, or roughly 250 students.

Chronicle

2013.01

Test chamber floor completed.
Electrical room equipment installed.
Pneumatic cabinets installed.
Construction Specification Canada presentation at Fanshawe.

2013.02

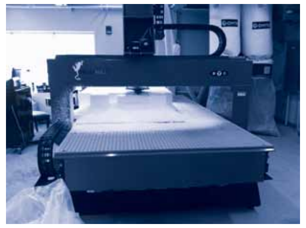
Fan walls begin installation/assembly.
Delivery of lower 100 fans begins.
Lift and turntable factory test.

2013.03

Test chamber ceiling complete.
Hanger doors being install.
Visit from Minister for Innovation.
Senior Alumni tour.

2013.04

Mechanical room outfit.
ABB drives installed. 60 fan wall begins.
Turntable installed.
Router delivered.

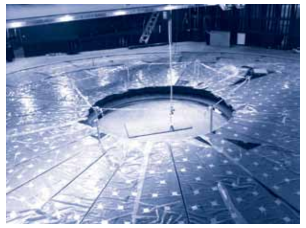


2013.05

Hotwire and router start-up and training.
External metal staircase.
Crane/traverse system installed.
VFDs powered.
Association of Architectural Technologists of Ontario tour.

2013.06

Wood floor install begins.
Fan wiring.
Outdoor concrete pad poured.
Building network equipment.



2013.07

First fan running.
Fan, pneumatics and guillotine start-up.

2013.08

Outdoor platform assembled.
Federal Economic Development Agency visit.

2013.09

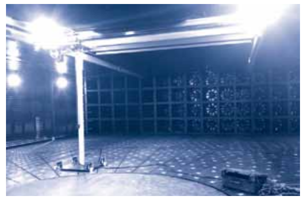
WindEEE Construction Complete.
Toronto : MaRS tour.
Magna International visit.

2013.10

First tornado visualization.
German Solar visit.
Novus Environmental visit.

2013.10

WindEEE Scientific Symposium.
Public Lecture by Lord Julian Hunt .
Open House Day.



2013.11

Outdoor turntable fabrication begins.

Institute for Catastrophic Loss Reduction tour.

Industry Canada Tour.

Commissioning begins.

2013.12

Ministry of Research and Innovation tour.

Contraction system delivery.

2014.01

Yukio Tamura visit.

Zurich Insurance visit.

2014.02

Staff and Leaders conference.

Don Smith Commercial Building Awards : WindEEE - Industrial Technology Achievement Winner.

Hydro One visit.

2014.03

Oxford Scientific filming : BBC One - Wild Weather with Richard Hammond.

Mechanical and Materials Engineering tour.

TrojanUV Water Solutions tour.

Professional Engineers Ontario (PEO) tour.

State Farm visit.

Barcelona : *All under Control* group meeting.

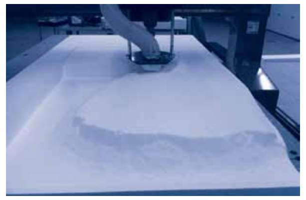
2014.04

Outdoor turntable install.

Canadian Foreign Affairs tour.

Advisory Council of Western Engineering meeting.

Ontario Centres of Excellence visit.



2014.05

PIV equipment delivered.

First model (Bolund peninsula) model manufactured.

Paris : Horia Hangan, invited professor at Le Laboratoire Interdisciplinaire des Energies de Demain (LIED)

2014.06

WindEEE Media Day.

WindEEE welcomes new Research Scientist (Maryam Refan).

Copenhagen: *Torque* conference.

Lord Julian Hunt Convocation.

2014.07

Turning vane install.

Directors Club meeting.

The Weather Network filming.

First downburst flow visualization and measurements.

Genova : *in-vento* conference

2014.08

American Society of Civil Engineers conference tour.

Tillsonburg, Ontario : Siemens wind turbine blade manufacturing facility visit.

Association of Municipalities of Ontario tour.

Media

Oxford Scientific Films / BBC One - Wild Weather with Richard Hammond

http://www.oxfordscientificfilms.tv/portfolio-item/wild-weather/

http://www.terramater.at/productions/richard-hammonds-wildest-weather/

The Weather Network

http://www.theweathernetwork.com/videos/gallery/all/video_gallery/its-a-tornado-in-a-box/sharevideo/3721834638001

Engineering News Record June 9 2014 (cover, p 44 and 47)

http://enr.construction.com/buildings/design/2014/0609-researchers-generate-tornadoes-on-demand.asp

Business London Oct 2013 (cover, p 32-37)

http://www.myvirtualpaper.com/doc/Business-London-Magazine/bl_october_2013/2013100302/#2

Canadian Geographic Oct 2013 (p 26)

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http://london.ctvnews.ca/video?clipId=378601

AM980 Radio

http://www.am980.ca/2014/06/09/20355/

Metro

http://metronews.ca/news/london/1060282/welcome-to-the-western-university-tornado-factory/

London Free Press

http://www.lfpress.com/2014/06/09/doing-the-twister

The Globe and Mail

http://www.theglobeandmail.com/technology/science/new-wind-research-laboratory-seeks-to-understand-effects-of-storms/article19131506/

Notes

Notes

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