A PARAMETRIC APPROACH FOR BUILDING-INTEGRATED WIND ENERGY INCORPORATING PASSIVE AND ACTIVE FLOW CONTROL TECHNIQUES

by

Ajith Mulky Rao

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Approved by the
Examining Committee:

____

Anna Dyson, Thesis Adviser

____

Jason Vollen, Member

____

Mark Mistur, Member

____

Michael Amitay, Member

____

Pravin Bhiwapurkar, Member

Rensselaer Polytechnic Institute
Troy, New York

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ABSTRACT

This dissertation proposes and evaluates techniques for the integration of active air flow control into building envelopes in order to allow for diverse and flexible applications for managing air flow including amplification for more effective capture of wind power. Existing building-integrated wind approaches have typically utilized large turbines to ensure high energy yields; this has restricted the viability of building-integrated wind in most built-up areas, where the presence of low wind speeds reduces the energy output, and the large turbines create myriad structural, aesthetic and acoustical challenges. Smaller turbines have not yet proved viable for ubiquitous applications as their outputs are hampered by the air flow conditions within urban areas. This research proposes and evaluates the use of active flow control to overcome the limitations of current strategies for building-integrated wind energy capture by enhancing the energy yields of small turbines, thus avoiding many of the problems faced by using large turbines on buildings.

As a point of departure, the research uses air flow amplification geometries from the Wind Amplified Rotor Platform (WARP) system as a baseline to establish the passive amplification of air flow through the physical aerodynamic shaping of the building envelope and investigates the viability of 'virtually' reproducing the amplification through the use of active flow control techniques. Geometric principles from the WARP were first incorporated within building envelope designs in simulation studies for the purpose of analyzing various parameters for the passive amplification of wind flows. In comparing the cost to benefit ratios, the energy produced was included in a parametric trade-off analysis framework that included various factors for construction complexity and cost associated with passive amplification techniques. The value proposition for active amplification techniques was analyzed through the integration of synthetic jets within building studies in order to test their potential for increasing energy yields from small turbines mounted on bluff building envelopes.

A series of wind tunnel tests were conducted based on the simulation studies, which demonstrated the capability of active flow control to replace the use of passive techniques for air flow amplification. The simulations and experiments ultimately culminated in the development of a parametric decision making construct that integrated the complex analysis of wind energy generation with a synergistic approach to air flow management. The conclusions from this research show potential for an extremely significant role for active air flow control techniques for the extraction of wind energy within building envelope assemblies. Additionally, the significant synergistic benefits from incorporating active air flow control for more efficient building construction and operational energy use point towards the necessity for further research to investigate the myriad benefits that could result from the transfer of this emerging technology from the field of aeronautics to building applications.