JOHNS HOPKINS
Center for Environmental
& Applied Fluid Mechanics

SPECIAL CEAFM Seminar

Friday, April 18, 2014 at 3:00 p.m. (Special Date & Time)

Ames Hall # 234 (Special Location)

DR. JOHAN MEYERS

Dept. of Mechanical Engineering, KU Leuven, Belgium

"Optimal Control of Wind Farms and Wind-Farm Boundary Layers"

In very large wind farms, the effect of turbine wakes, and the accumulated local energy extraction from the atmospheric boundary layer leads to a reduction in farm efficiency, with power generated by turbines in a farm being lower than that of a lone-standing turbine. In this process, atmospheric turbulence plays an important role. On the one hand, it is beneficial, since the overall energy extraction in large wind farms is regulated by the vertical turbulent transport of kinetic energy from higher regions in the boundary layer towards the turbine level. On the other hand, turbulence leads to increases power variability and fatigue loading. The current talk addresses the use of optimal control techniques as a benchmark for wind-farm control. The talk consists of two parts. In the first part, optimal control is used to enhance power extraction in wind farms, using the wind turbines as flow actuators. The optimal control framework in this case consists of large-eddy simulations of a wind-farm boundary layer, in which turbine controls are optimized in a receding time-horizon approach. For the wind-farm case considered in our study, we show that energy entrainment rates towards the turbines can be increased with up to 20%. In the second part of the talk, optimal control of the rotating kinetic energy of the turbines is discussed. Here the aim is not to increase energy extraction or turbulent entertainment, but given a turbulent wind field, to decrease the level of power fluctuations in the wind-farm output. Since turbines have rotational inertia, they all have some rotating kinetic energy reserve. These can be exploited to smooth the electric power output, by temporarily increasing or decreasing the turbines' rotation, instead of directly feeding all of the fluctuating aerodynamic power to the generator. It is shown that coordinated control in large farms allows to significantly smooth power up to time scales of one minute, while keeping the decrease in energy extraction limited.