The Wind in Spain

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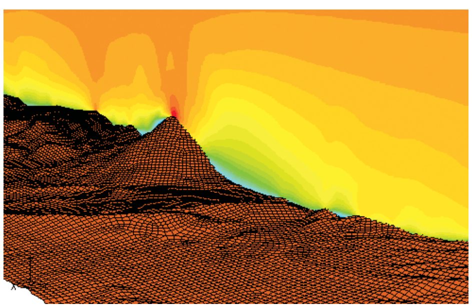
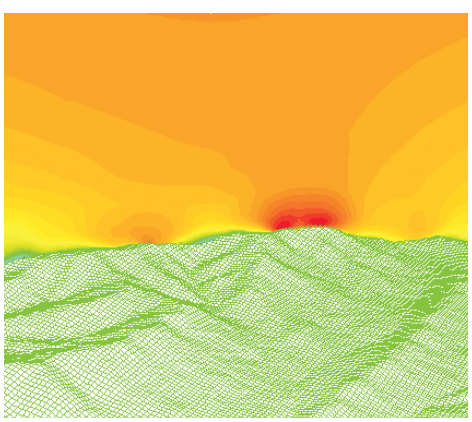
The site in northern Spain considered in the study



Velocity contours on a plane slicing through the highest peak in the landscape show a variety of wind speeds near ground level



Velocity contours are more uniform in regions where the topographical variation is less

Harvesting wind from mountainous regions is an appealing option in many countries, where flatter land is often put to housing, industrial, or other community use, and citizens prefer that power generation facilities of any kind not mar the nearby landscape for most people on most days. Several software programs are currently available to assess the wind power generation potential of a given site, but they are not, as a rule, well suited to steep terrain. CFD is now emerging as an alternative tool for wind source assessment and forecasting, and its growing popularity is due, in part, to its ability to simulate wind conditions for any type of terrain.

In a recent project carried out at the National Renewable Energy Center of Spain (CENER), a CFD study of a region in Navarre, south of Pamplona in the northern part of the country, was performed. Using a square expanse of land, 14 km on a side, as a footprint, the atmosphere was modeled to a height of 7 km. Digitized contour data, with one node every 50 m, was used to replicate the surface of the land for the CFD model. The quad paving scheme in GAMBIT was used for the surfaces, and a volume mesh of 1.5 million hexahedral elements was built. Using FLUENT, customized boundary conditions for velocity (a logarithmic wind profile) and turbulent kinetic energy and dissipation were applied using user-defined functions (UDFs). Through the use of wall roughness factors characterized by different length scales, different vegetation patterns on the land were simulated using the wall function. Four meteorological masts located at the site were used to collect wind speed and direction data at several heights for a period of one full year. Pair-wise correlations from two measurement stations were used to validate the CFD predictions for average wind speed and power density. The results were also compared to the predictions of one of the simpler wind analysis programs typically used in the industry.

The results showed that the average absolute error between the CFD predictions and measured values for wind speed was 4.4%, while it was 6.6% for the simplified wind analysis program. For the power density, the average absolute errors were 4.9% and 13.4%, respectively, for the CFD and wind analysis program predictions. For both numerical methods, the error was found to increase with the spacing between the stations used for the correlation. This increase was greater for the wind analysis program, however, suggesting that as the distance between meteorological masts increases during site assessment studies, it is more beneficial to use CFD than a simplified code.

The methodology developed can now be used with confidence to evaluate the wind conditions in the vicinity of each turbine position planned when a wind farm is designed. It is especially recommended when accuracy in the predictions is important (to minimize the financial risk), when there are few meteorological masts near the planned turbines, and when the terrain is complex. Models are currently under development to test different turbulence models and include wake effects. ■