# Turning a New Leaf

**By designing a tree-like wind power generator with steel branches and plastic leaves, New Wind has created an aesthetically pleasing alternative energy source for urban environments, bringing energy generation closer to people.**

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## “Engineers were able to perform *fluid–structure* interaction *multiphysics simulations* to develop a robust, efficient *plastic leaf* for the wind tree.”

While walking through the Jardin du Luxembourg, a beautiful garden square in Paris, Jérôme Michaud-Larivière noticed that the leaves on the trees were trembling though the air was calm. Michaud-Larivière knew that movement means energy, and if harnessed, it could be used to generate electricity. What if, he thought, you could build a wind-based energy generator on a human scale, closer to people in urban environments, something that would blend in aesthetically with the garden scenery, something like — a tree?

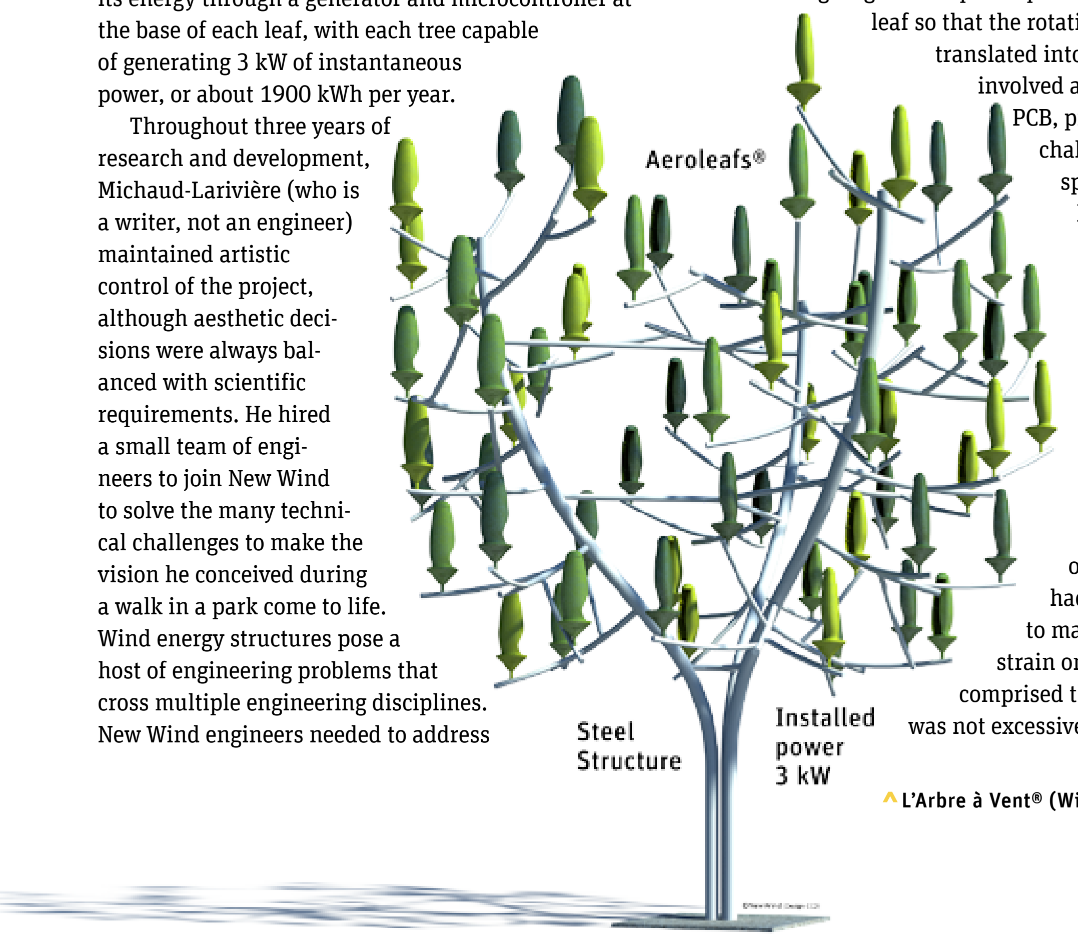
As a result, he started a company called New Wind that has designed l’Arbre à Vent® (the wind tree) — a 10-meter-high, 7.5-meter-wide tree-shaped wind turbine with a steel trunk and branches and 63 plastic “leaves” (called Aeroleafs®). These leaves capture the wind and transfer its energy through a generator and microcontroller at the base of each leaf, with each tree capable of generating 3 kW of instantaneous power, or about 1900 kWh per year.

Throughout three years of research and development, Michaud-Larivière (who is a writer, not an engineer) maintained artistic control of the project, although aesthetic decisions were always balanced with scientific requirements. He hired a small team of engineers to join New Wind to solve the many technical challenges to make the vision he conceived during a walk in a park come to life. Wind energy structures pose a host of engineering problems that cross multiple engineering disciplines. New Wind engineers needed to address issues such as wind loading, durability, electronic generators and controls. ANSYS electronic, fluid and structural design software solutions played a large role in overcoming these multiphysics challenges.

### DESIGNING A WIND TREE

There were many engineering challenges. Each artificial leaf had to capture the available wind with maximum efficiency, so their physical shape and size were critical. Determining the optimal number of leaves on a tree of the desired size was also important, along with their placement in the 3-D volume of the tree. How do you locate them so that one leaf doesn’t interfere with the ability of its nearest neighbor to capture its share of wind, which could be blowing from any direction?

Designing a small power plant into the base of each leaf so that the rotation of the leaf could be translated into electricity on the spot involved a set of magnets and a PCB, presenting electromagnetic challenges. Also, the optimum speed of rotation of the leaf had to be controlled to maximize power generation efficiency. Structurally, the forces on each plastic leaf in high winds had to be calculated to ensure that the resulting strain would not cause the leaf to fail. The combined stresses of the wind on the leaves had to be taken into account to make sure that the overall strain on the structural steel that comprised the trunk and branches was not excessive.

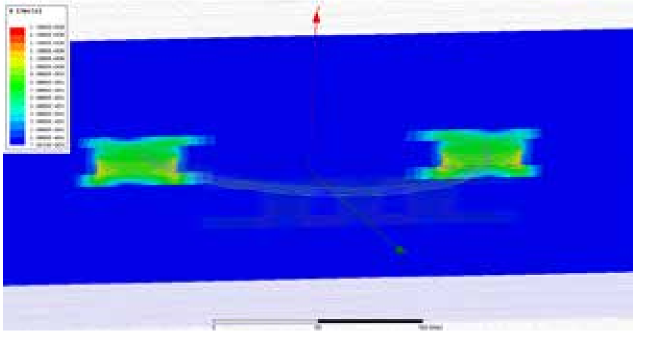



^ L’Arbre à Vent® (Wind Tree) model

> "New Wind engineers were able to **design and predict** the real-world operation of the **aerodynamic**, structural and electromagnetic parameters of the **wind tree.**"

## ENGINEERING A FUNCTIONAL LEAF

The engineering team realized that the best approximation to a leaf would involve a commonly used vertical-axis wind turbine on a rotating shaft called a Savonius turbine. These turbines are typically cylindrical, with two opposing quadrants cut out to form curved, S-shaped scoops that catch the wind and spin the turbine on its axis, creating torque. Because a cylindrical leaf was not acceptable for aesthetic purposes, an ellipsoid shape was chosen instead.



^ Dynamic 3-D magnetic field simulation with ANSYS Maxwell allowed engineers to determine plate thickness, type of magnets, material used for plates, thickness of the air gap and size of the magnets for each leaf generator.

Engineers began the design work using an open-source software simulation package, but it soon became apparent that time-consuming software modifications would be necessary to perform the required simulations. Based on previous academic and professional experience with ANSYS solutions, New Wind engineers chose ANSYS Fluent, ANSYS Mechanical and ANSYS Maxwell to tackle the aerodynamic, structural and electromagnetic challenges they faced. They were soon performing fluid–structure interaction multiphysics simulations to develop a robust, efficient plastic leaf for the wind tree.

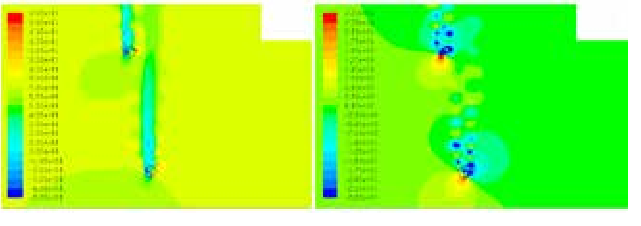
Efficiency, along with the predetermined size and shape of the tree, placed limits on the possible range of leaf dimensions. The leaves had to be large enough to efficiently capture the wind and small enough to be aesthetically proportional to the rest of the tree. Engineers ran parametric simulations using ANSYS Mechanical and ANSYS Fluent to determine the optimal leaf size and material. The leaf size ultimately was determined to be 376 mm at its widest point. It was constructed of acrylonitrile butadiene styrene (ABS), an inexpensive and readily available plastic. This design optimized wind-capturing efficiency and acceptable strain on the leaf during high-wind conditions. Based on wind-tunnel tests of two leaves, they determined that a maximum of 63 leaves could be distributed on the tree structure.

## CHECKING FOR AERODYNAMIC INTERFERENCE

Sixty-three leaves was the theoretical maximum based on two assumptions:

- The individual influences of any number of leaves on a randomly chosen reference leaf can be added to give the overall influence on the reference leaf.
- The influence of two leaves on each other does not depend on their locations.

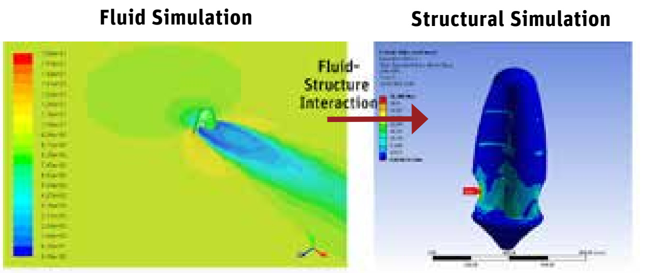
These assumptions had to be confirmed using CFD simulations before the engineers could proceed with the design based on 63 leaves. If the first leaf to encounter wind blowing from a certain direction prevented sufficient wind from reaching a nearby leaf, energy efficiency would be impaired. Interactions between leaves had to be minimized.



^ Using fluid dynamics simulation, engineers were able to determine placement of the leaves on the tree so that the wake of one did not affect the next leaf and more power could be generated. Simulations show little effect from wind speed (left) but significant interaction from static pressure (right).

The aerodynamics team used ANSYS Fluent CFD simulations to study the wind flow around a leaf under various velocity and directional conditions to determine the nature of flow in the wake behind a given leaf. Essentially, these simulations were performed to validate the experimental results of two leaves in a wind tunnel, which the team had done earlier. Fluent CFD results confirmed the experimental results of the wind-tunnel tests to a good approximation. CFD showed that the wake of one leaf did not affect the efficiency of a nearby leaf. Also, simulation of three leaves confirmed the assumption that the influence of a number of leaves on a reference leaf can be summed. So 63 leaves was a valid number.

Finally, engineers performed a 3-D Fluent simulation on one leaf to measure the power coefficient, which is the ratio of the actual power that you can extract from a wind turbine of a particular design over the maximum available power. For the ellipsoidal leaf design, the power coefficient is 20 percent. Calculation of this value depends on the ratio of the speed of the rotating leaf and the wind speed. These two speeds will be important in describing the electromagnetic design of the wind tree.




^ The structure of the ABS wind turbine was examined using fluid–structure interaction.

## PERFORMING ELECTROMAGNETIC SIMULATIONS

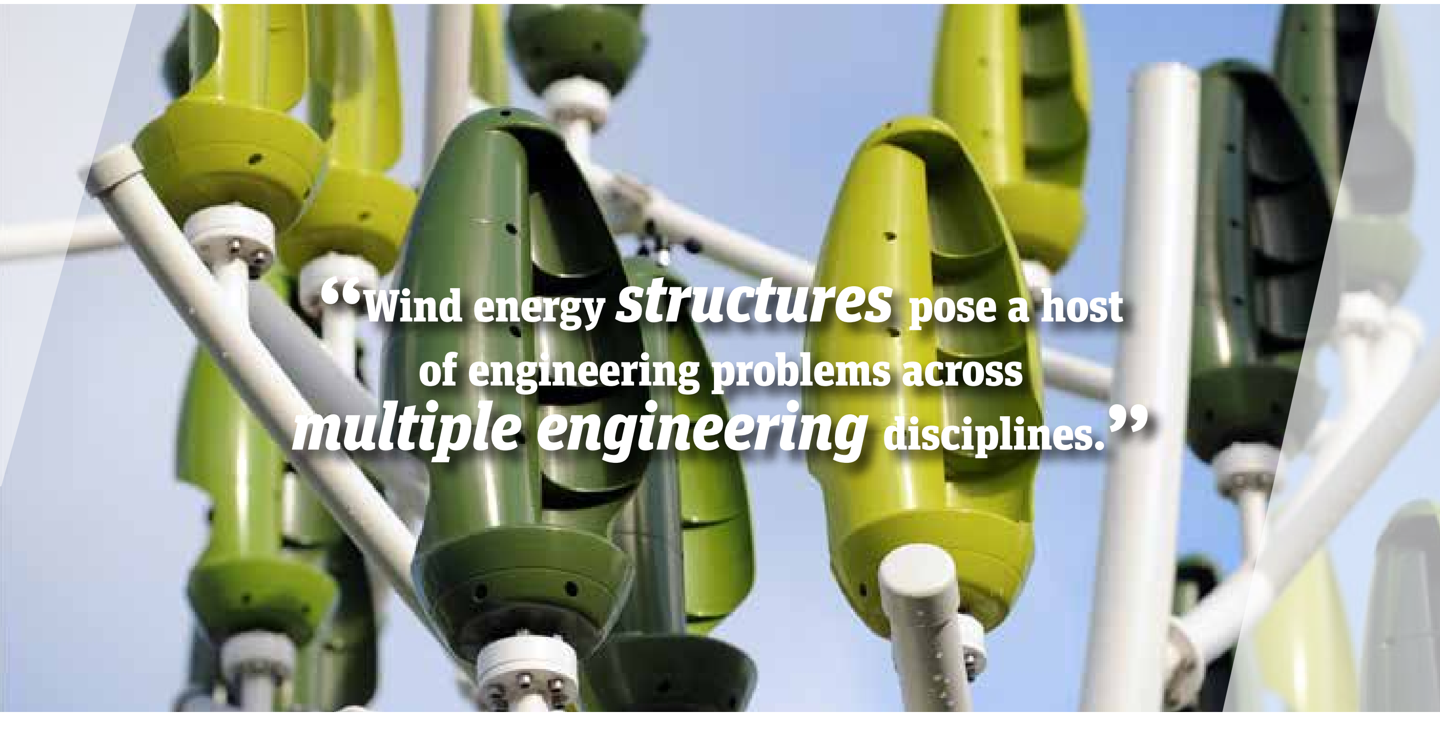
Each leaf of the wind tree has an electrical generator in its base comprising 16 coupled magnets on the rotor. The magnets move with the rotating leaf and coils on a PCB that together produce a three-phase voltage proportional to the rotation speed of the turbine and the magnetic field in the air gap.

New Wind engineers used ANSYS Maxwell simulations to design the generator, including specification of magnetic plate thickness, type and size of magnets, material used for the plates, and thickness of the air gap. A 3-D static magnetic field simulation was performed to determine the mean magnetic field in the air gap, while a 3-D dynamic magnetic field simulation was run to predict power generation parameters, such as induced current and voltage.

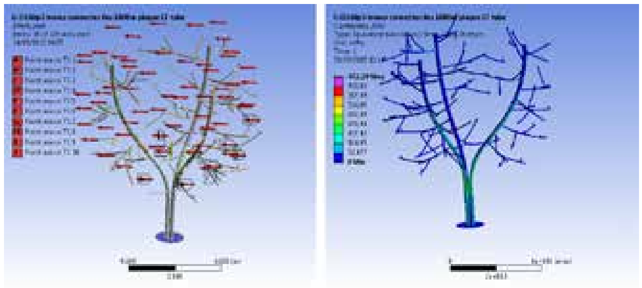
Each leaf generates an alternating current that is transformed into a continuous current (DC). A microcontroller in the bottom of the leaf controls the current of each mini wind turbine. For each leaf there is an optimum ratio between its rotation speed and the wind speed. To extract the maximum energy possible — 20 percent — from a New Wind–type leaf, it is important that the leaf rotates at a speed that produces this optimum ratio for the specific incoming wind speed. The microcontroller regulates the rotation speed of the leaf to achieve this ratio every time.

## SIMULATING TRUNKS AND BRANCHES

In addition to fluid–structure interaction simulations performed with Fluent and Mechanical on the plastic leaf to ensure that stresses would not exceed the elastic limit of the ABS material, New Wind engineers also ran structural simulations on the steel framework of the wind tree. They



performed static structural calculations with Mechanical to determine the static loading on the 63 turbines, modeling each as a point mass with an assigned mass value where it was attached to the framework. They also extracted the shell model from a CAD model. By allocating masses and wind forces acting on each turbine, these simulations confirmed that stresses were within acceptable limits everywhere on the wind tree.



^ **Wind loading was examined using structural simulation.**

### MAKING WIND ENERGY CHIC

With the help of ANSYS Fluent, Mechanical and Maxwell engineering simulation solutions, New Wind engineers were able to design and predict the real-world operation of the aerodynamic, structural and electromagnetic parameters of the wind tree that their company's founder had envisioned only a few years before.

The first prototype wind tree was "planted" in Bourget in 2015, and a wind tree was put on display at Roland Garros, the site of the annual French Open tennis tournament, in May 2016. Reviews from people were overwhelmingly positive. Some large companies and municipalities have expressed interest in purchasing and installing wind trees around the EU. Engineering work, including simulation, continues in an effort to further improve all aspects of the wind tree's operation, and to reduce its cost. While the wind tree is not going to replace large-scale wind farms because it can't produce as much power, New Wind hopes to change the image of wind power in general to a more positive one by demonstrating it in a pleasing form on a human scale. Λ

**Fluid-Structure Interaction**
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