

**Comparison of fluid-mechanical key indicators :**

- DualWingGenerator laboratory set-up measurements
- Comparative values of small system 1\*
- Comparative values of small system 2\*

\* For the comparative objects, an electromechanical effectiveness level of 80 % was assumed.

On file: prevailing wind speeds in continental central Europe

**Amazing result:** ultimate effectiveness level at low wind speeds, as prevail in central Europe

**Scientific proof of energy efficiency**

In numerous measurements on a laboratory set-up, the system's aerodynamic and mechanical effectiveness levels were determined and then compared with the outputs of two conventional wind power stations of the same size. The test system was set up so that the influences on all the key parameters could be adjusted and recorded in a wind tunnel. So-called PIV (particle image velocimetry) measurements were used here to accurately determine the speed distribution on and between the aerofoils over the course of time.

**Ultimate effectiveness levels at low wind strengths**

Particularly in the range of the most common wind speeds between 4 and 8 m/s, the DualWingGenerator revealed remarkable outputs compared to small wind power stations. On the laboratory set-up, it achieved a fluid-mechanical effectiveness level of 45%, whereby up to 59% is possible in theory. Efficiency levels can therefore be increased considerably in comparison with conventional small systems – especially with low wind strengths, as prevail in continental central Europe.

**Various fields of use and applications**

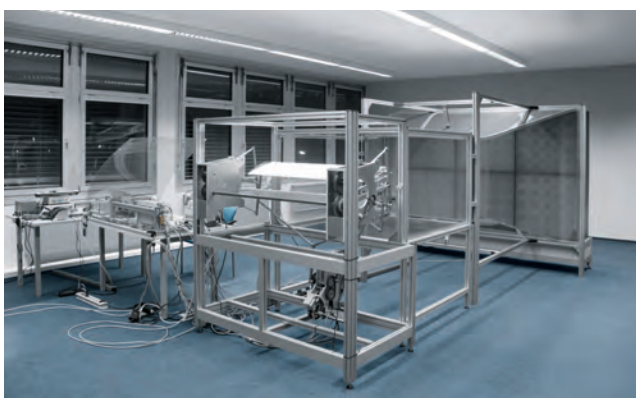
The knowledge acquired leads to completely new ways of using wind generators. Whilst large wind parks have a high land use and, as a consequence, only pay for themselves out at sea, a system like the DualWingGenerator could be installed almost anywhere – even easily on buildings.

The local solution works like a sun collector but rather as a wind collector and also reduces the costs for connecting to the mains network.

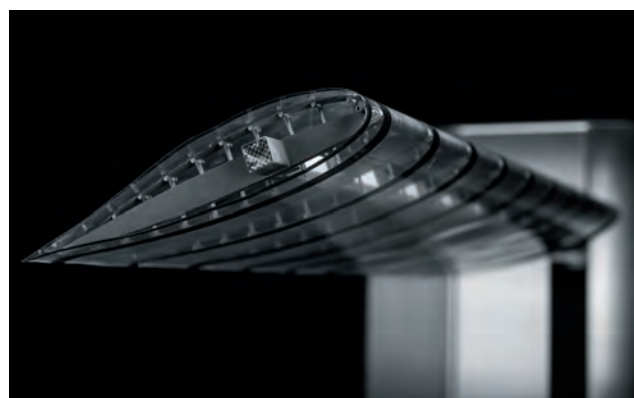
Besides the electric generator for producing electricity, other appliances for tapping the mechanical energy are also conceivable – for example, a compressor for generating compressed air or a water pump for use in process automation.

**Further development with adaptive wings**

To increase the efficiency of the system even further, instead of the rigid aerofoils, Festo is also testing adaptive wings with Fin Ray Effect®. The wing profile changes depending on the angle of incidence and the efficiency of the whole system is increased.



Continuous testing: whether in a scientific laboratory set-up ...



... or through the development of the material



#### Technical data

##### System:

- Total width: 250 cm
- Integrated components:
  - 1 ELGG axle
  - 2 free wheels
  - 2 push-on flanges
  - 2 motor flanges
  - 1 CPX-CEC-M1 control system
  - 1 8DI/8DO module
  - 1 2AI module with 2 analogue inputs
  - 1 electricity generator as a
  - 120 W braking dynamometer

##### Wing:

- Width: 110 cm
- Profile: NACA0014
- Material: Carbon

#### Project participants

##### Project initiator:

Dr Wilfried Stoll, managing partner,  
Festo Holding GmbH

##### Project management:

Dr Heinrich Frontzek, Elias Knubben,  
Festo AG & Co. KG

##### Project team:

Matthias Gehring, Uwe Neuhoff,  
Festo AG & Co. KG

##### Design and scientific support:

Dr Wolfgang Send, Felix Scharstein,  
ANIPROP GbR in Göttingen

##### Development of adaptive wings with Fin Ray Effect®:

Rainer Mugrauer,  
Effekt-Technik GmbH, Schlaitdorf

Fin Ray Effect® is a brand of Evologics GmbH, Berlin



→ Film

#### Festo AG & Co. KG

Rüter Straße 82  
73734 Esslingen  
Germany  
Phone +49 711 347-0  
Telefax +49 711 347-21 55  
cc@de.festo.com  
www.festo.com/bionic

# DualWingGenerator

**FESTO**



**Power generation  
with the wing-  
beating principle**

# Self-optimising system for ultimate plant efficiency and process reliability



With the DualWingGenerator, as part of the Bionic Learning Network, Festo has developed an extraordinary technology platform that uses two pairs of horizontally arranged wings instead of rotor blades to generate power.

Thanks to its intelligent control technology, the self-optimising system can adapt itself to different wind conditions and, in terms of its efficiency, is by no means inferior to conventional small wind power stations. The concept features amazing benefits even at low wind speeds.

## Reverse principle of the natural beating of wings

The system's principle consists of reversing the natural wing-beating principle: whilst birds generate the necessary power to move forwards in the air by flapping their wings, a stationary system like the DualWingGenerator can take the kinetic energy from the flow of air. The wind power creates a linear lifting movement here, which is converted into a rotary movement. With the aid of an electric generator, the system turns the energy produced into electricity.

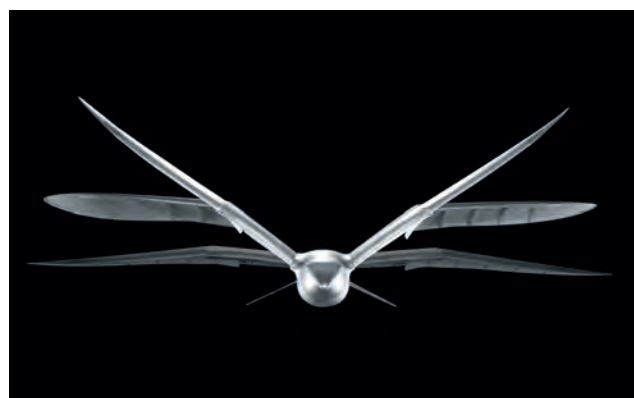
## Oposing pairs of wings for optimal power generation

The four wings are arranged on both sides of the central column. The two top and the two bottom wings are each positioned on the same motor-driven rotary axle, which is fitted on a slide. When the wind blows, the two slides move synchronously on the vertical guide in opposing directions: whilst the top two wings travel upwards, the bottom wings move downwards. The pair of wings on one side forms a functional unit, whose fluid-mechanical properties enable power to be generated in an optimal manner. At the apex, a servomotor turns the wings and they automatically move back towards each other.

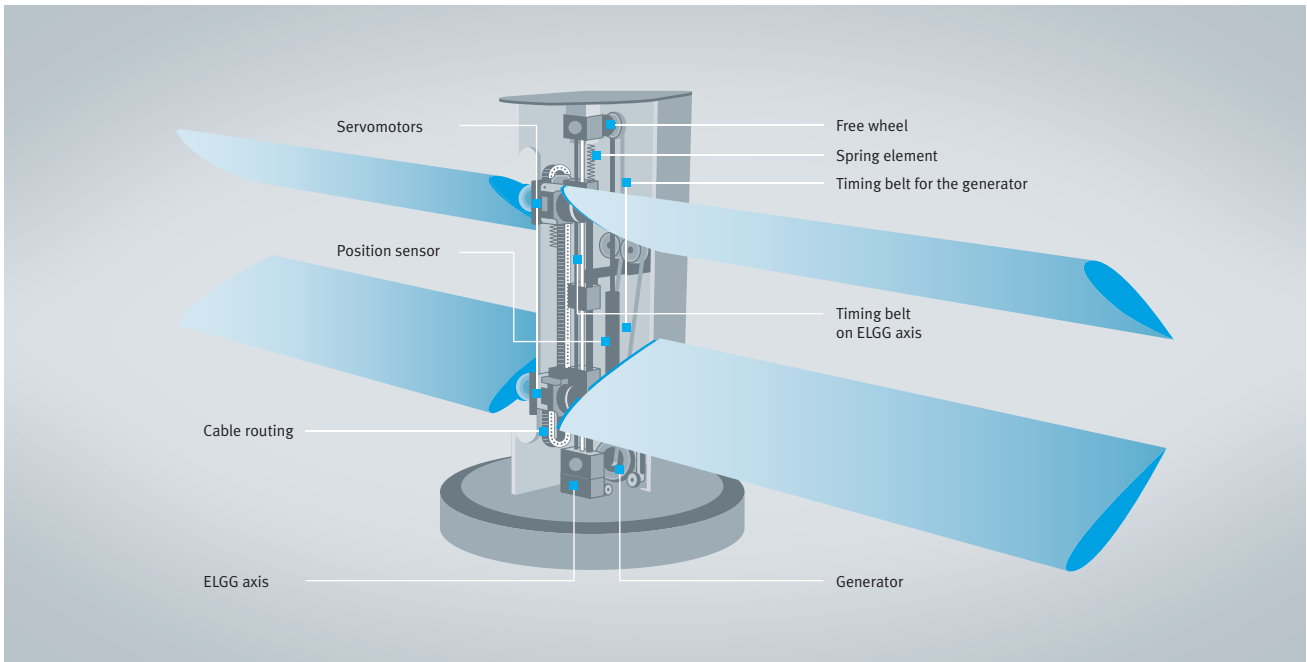
Their active rotation means the wings are always set so that air flows onto them at the optimal angle. This enables the adaptive system to achieve an optimal energy yield with a very high, scientifically proven effectiveness level. Festo already technically implemented this so-called active torsion in 2011 with the SmartBird. When developing the artificial silver seagull, the engineers studied how birds actively rotate their wings and thus make the most energy-efficient use of the wind conditions.



**New concept:** opposing pairs of wings with linear lifting movement ...



... and active wing rotation modelled on the bionic SmartBird



**Highly complex controls:** coordinated correcting variables for greater plant efficiency and process reliability

#### From lifting movement to electrical energy

The whole mechanism used to turn the wind power into electrical energy is integrated in the central column on the DualWingGenerator. The column also contains the sensor technology, which helps to optimise the mechanical movement and enable it to be adapted to the wind conditions in an energy-efficient manner.

If air flows towards the system, the central column turns automatically and always directs the wings, made of carbon, at right angles to the oncoming wind.

The flow of air thereby acts on the aerofoils of the wings, which are lined up at an appropriate angle by the servomotors. This leads to the slides moving up and down on the axle with the wings, which produces the opposing movement of the wings. The movement is synchronised in opposite directions using a timing belt, which transfers the force to two bearing shafts. These rotary movements are rectified by means of free wheels and transferred to the generator using another timing belt. The wind power thus generates firstly kinetic and finally electrical energy.

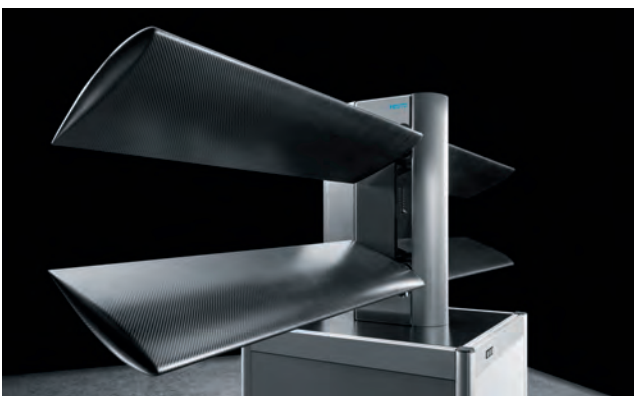
Whilst the wings are moved by the oncoming wind, the system only has to provide power for the two servomotors and for the CPX control system, which is installed under the central column.

#### Higher system efficiency due to tandem wings

The utilisation of two pairs of wings with only one central column allows the wing area to be doubled – with the mechanical layout remaining the same and hence the same friction. This increases the area of wind contact in relation to the mechanism and hence the efficiency of the system.

The opposing tandem wings neutralise the bearing torques from the upwards and downwards motion. In the middle, the wings get so close that a suction effect is created between the aerofoils, which enables a higher level of effectiveness.

When the wings move towards each other, the air between them speeds up. In turn, this acceleration creates a drop in pressure, which pulls the two aerofoils together and thus further increases the energy yield.



**Optimal reversal points:** active controls to preserve the mechanics ...



... and to make efficient use of the prevailing wind forces



**Decentralised power generation:** highly efficient conversion of wind power into electricity

### **Self-optimising system in all wind strengths**

As the wind speed is normally changing constantly, the system must react accordingly to its environment. Thanks to its intelligent control technology, the DualWingGenerator can adjust itself to different surrounding conditions and always sets itself at right angles to the wind direction.

In order to produce as much energy as possible, the system must optimally coordinate six key parameters to the respective wind speed.

#### **1. The flapping frequency of the wings**

How fast a wing flaps essentially depends on the mechanical properties of the system. A certain variation range results from the wings' angle of incidence as well as the load that is exposed to the wind – in other words, how much energy is taken from the system. The following rule applies here: the higher the load, the greater the braking effect on the kinematics.

#### **2. The amplitude of the wing beat**

How far the wings travel apart and come back together during their lift is determined by the triggering of the rotary movement. This point in time can also have a critical influence on the distance between the wings and hence the system's energy efficiency.

#### **3. The angle of incidence in the wing roots**

The system controls the angle settings for rotating the aerofoils towards the oncoming wind directly via the activation of the two servomotors.

#### **4. The time for triggering the rotation**

The point in time at which the wings are rotated can be controlled depending on the height of lift and is a key optimisation parameter. In this respect, the system adjusts to the respective situation in fractions of a second.

#### **5. The setting speed of the wing rotation**

How quickly the wings adjust their angle of incidence for converting the lift is also controlled by the motors in the wing roots.

#### **6. Stiffness of the preloaded springs**

How quickly the lift direction is converted depends on the additional energy that has been collected in the preloaded springs at both ends of the lift path before the direction conversion. The more energy that is available for accelerating the pair of wings after the direction conversion, the higher the lifting frequency.

The stiffness of the preloaded springs is currently a static parameter. The maximum angle of incidence, the time for triggering the rotation and the setting speed are dynamic parameters and can be optimised independently.

The system uses these dynamic parameters and the prevailing wind speed to derive the frequency and amplitude of the wing lift. When set in the optimal way, this creates the fluid-mechanical effects which allow the energy to be taken from the system efficiently.



**Functional unit:** the pair of wings on one side