Insects can halve wind-turbine power

For no apparent reason, the power of wind turbines operating in high winds, may drop, causing production losses of up to 25%[1]. Here we use a new flow visualisation technique to analyse airflow separation over the blades and find that insects caught on the leading edges in earlier low-wind periods are to blame. These potentially catastrophic power glitches can be prevented simply by cleaning the blades.

Unpredictable changes in power levels have been noted on wind farms in California, with power sometimes falling to half the output predicted from the turbine design and generating two or more different power levels at the same wind speed (Fig. 1a). Although this phenomenon (termed 'double' or 'multiple' stalling) has been investigated[2-4], the cause has remained unknown.

One study[5] commissioned by a turbine manufacturer (NEG Micon) used a new invention called a stall flag[6] (patent, Energy Centre of the Netherlands) as a flow-separation detector (Fig. 1b) to try and solve the problem. This device works on the principle of a hinged flap that opens up in a separated airflow to uncover an individual reflector (Fig.1c) which allows the flow to be visualised. Operation of a stall flag on a turbine with a rotor diameter of 44 metres is illustrated in Fog. 1d, in which the light tracks are from exposed reflectors and indicate where the blades stall.

We found that the stalling behaviour of the blades depends on the degree of contamination of the leading edges. However, the reduction in power should be continuous (as debris on the blades would be expected to accumulate gradually) rather than stepped in distinct levels as shown in Fig. 1a.

We considered the possibility that flying insects caught on the turbine blades could explain this effect. Insects prefer to fly in conditions of high air humidity, low wind and temperatures above about 10°C. Under these conditions, they will increasingly foul the leading edges of the blades. In low winds, the incident angle between the flow and the blades is small, which corresponds to low air velocity around the leading edges, so the blade is not susceptible to contamination of the leading edges and the power output is unaffected. Insects rarely fly in high winds, so turbines operating in steady high-wind conditions do not become contaminated and power levels remain constant.

In high winds, however, the angle between the flow and the blades increases and the aerodynamic suction peak (the area of minimum pressure and maximum air velocity) shifts to the leading edge. If this happens to be already spattered with dead insects, power output will fall: the greater the contamination at the suction peak, the sooner the blades will stall and the more lift will be lost (Fig. 1e). Thus after each period of low wind, the amount of insect contamination may change, causing a different power level to be produced in high winds.

We verified this hypothesis experimentally by using stall flagging to compare airflow over smooth blades with that over blades that have been artificially roughened on their leading edges (by installing a zigzag tape of maximum thickness of 1.15 mm) The two turbines were within 50 metres of each other to ensure equal inflow (Fig. 1f). A 25 Hz digital video camera recorded the stall flag signals, providing thousands of computer-processed images which indicated that flow separation on the roughened blades was significantly increased at wind speeds of 11-25 m s^{-1}. This effect extended over the entire blade span, which explains the previously observed power losses (Fig. 1a). Moreover, power output from rough- and smooth-bladed turbines was equal at low wind speeds, but higher from the 'clean' blades at high wind speeds (Fig. 1g), neatly reproducing the effect shown in Fig. 1a.

We also studied a time series for the power output from four different turbines and found that the power at high wind speeds decreased markedly after every period of low wind speed, rising again after the blades were cleaned either manually or by rain, as expected. It is likely that accumulation of ice or dirt on the blades could create distinct power levels in high winds in the same ways as insect contamination.

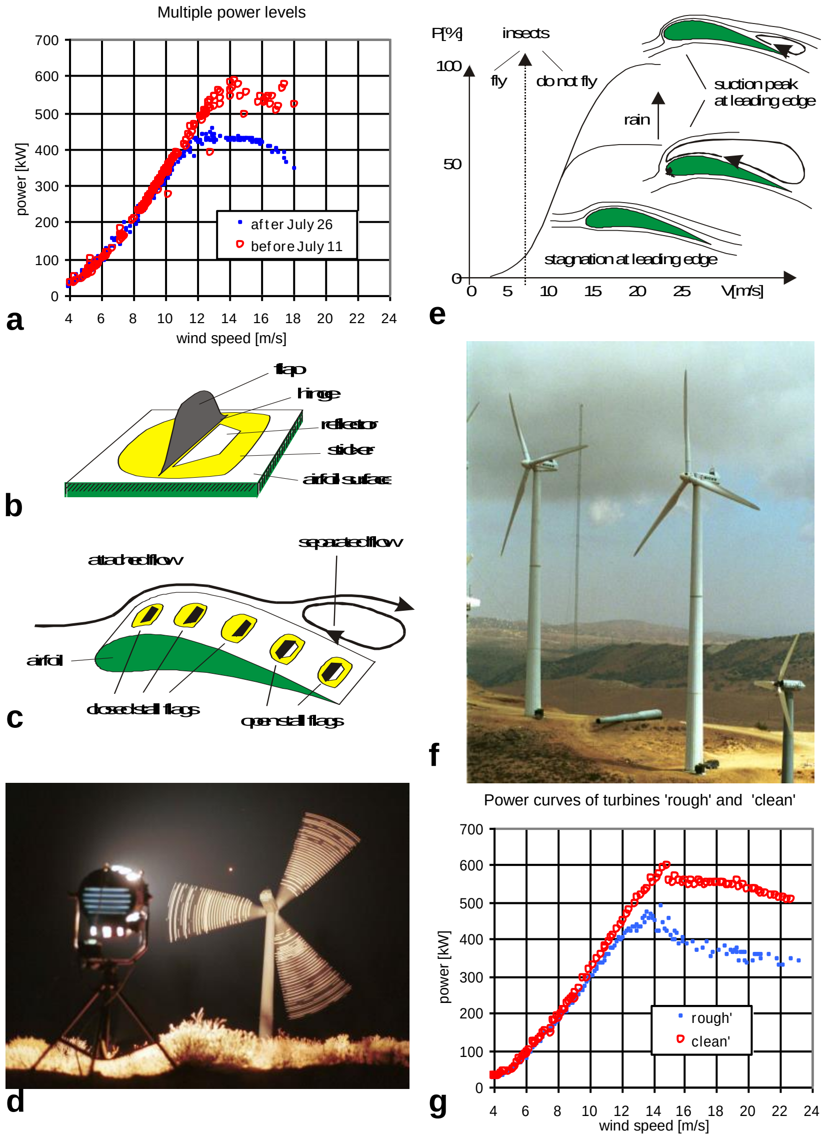

Figure 1 Insects cause multiple power levels from wind turbines. **a**, Example of two power levels at the same wind speed on different dates. **b,** The stall flag, consisting of a hinged flap and a reflector. **c**, Stall flags, showing the separated flow area on an aerofoil. **d**, Recording of stall flag signals from the NEG Micon turbine in California. The light tracks are produced by reflected light from open stall flags. **e**, Illustration of the insect hypothesis proposed to explain multiple power levels. **f**, The two turbines used for the validation of the insect hypothesis; these were only 50 m apart to ensure equal air inflow. **g**, The power curves for the two turbines with 'rough' and 'clean' blades, which are similar to those in **a**.

Gustave P. Corten*, Herman F. Veldkamp†
**Energy Centre of the Netherlands (ECN), Unit Wind Energy, P.O. Box 1, 1755 ZG Petten, The Netherlands*
e-mail: corten@ecn.nl
† NEG Micon A/S, Alsvej 21, 8900 Randers, Denmark

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