The SKARV System – Preventing bird strikes through active regulation of wind turbines

Characterizing the theoretical system performance

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A cormorant (skarv)

SKARV (Norwegian: <u>S</u>lippe fugle<u>k</u>ollisjoner med <u>a</u>ktiv <u>r</u>egulering av <u>v</u>indturbiner) is a collision avoidance control system for wind turbines. The idea is to detect incoming birds (or other flying objects like drone aircraft) and make a small adjustment to the rotor speed so that the blades and birds are not located at the same place at the same time. As opposed to alternative collision deterrants,

- The wind turbines keep operating, and
- The system is benign to birds and other wildlife, not employing "scare tactics" such as sounds or lights.

Figure 1 shows a possible architecture for the control system, introducing a speed perturbation to an existing torque/pitch controller.

Figure 2: A USB camera of the sort that might be used in the SKARV system. (en.ids-imaging.com)

The challenge of detection and tracking is to find a low-cost solution that can track small, distant, fast-moving objects in 3D. The sensor systems may employ visual and/or radar detection: stereo visual detection is particularly appealing, as USB cameras (Figure 2) are inexpensive. Modern cameras with USB 3 or GigE allow for fast, high pixel density image acquisition, and have a Log exposure function, which aids imaging against the sky; although night vision remains a problem.

Figure 3 shows an avoided collision, with the ideal placement of the rotor blades relative to the bird. Notice the large clearance as the bird passes through the rotor plane. This indicates that the collision can be avoided even if the bird makes evasive maneuvers; however the behavior of birds in the vicinity of wind turbines is a topic that requires further investigations including field data.

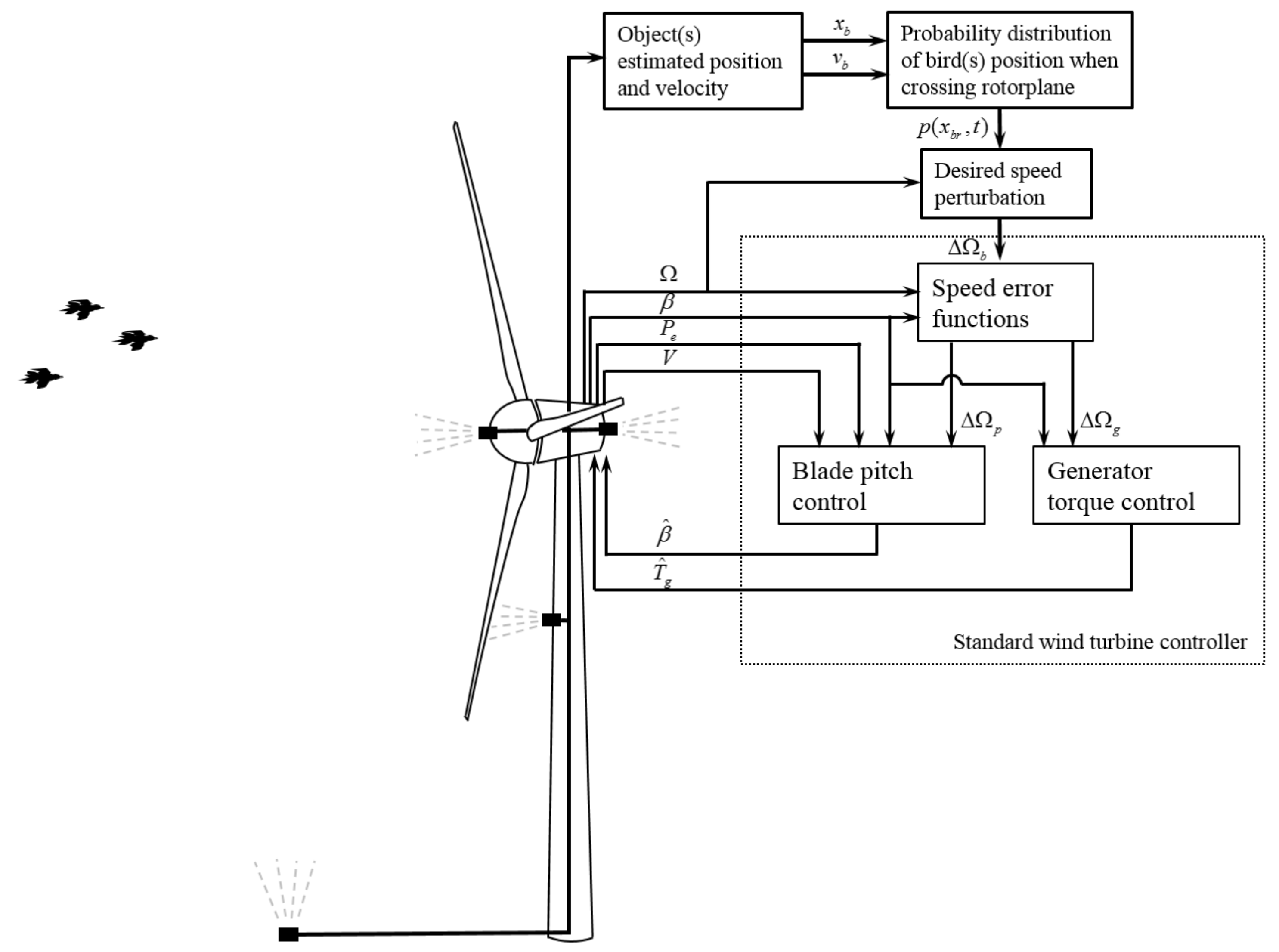

Figure 1: A possible architecture for the SKARV system, interfacing with a standard wind turbine controller. Preferably, working with an OEM, the collision avoidance functions could be implemented as part of the turbine's standard controller.

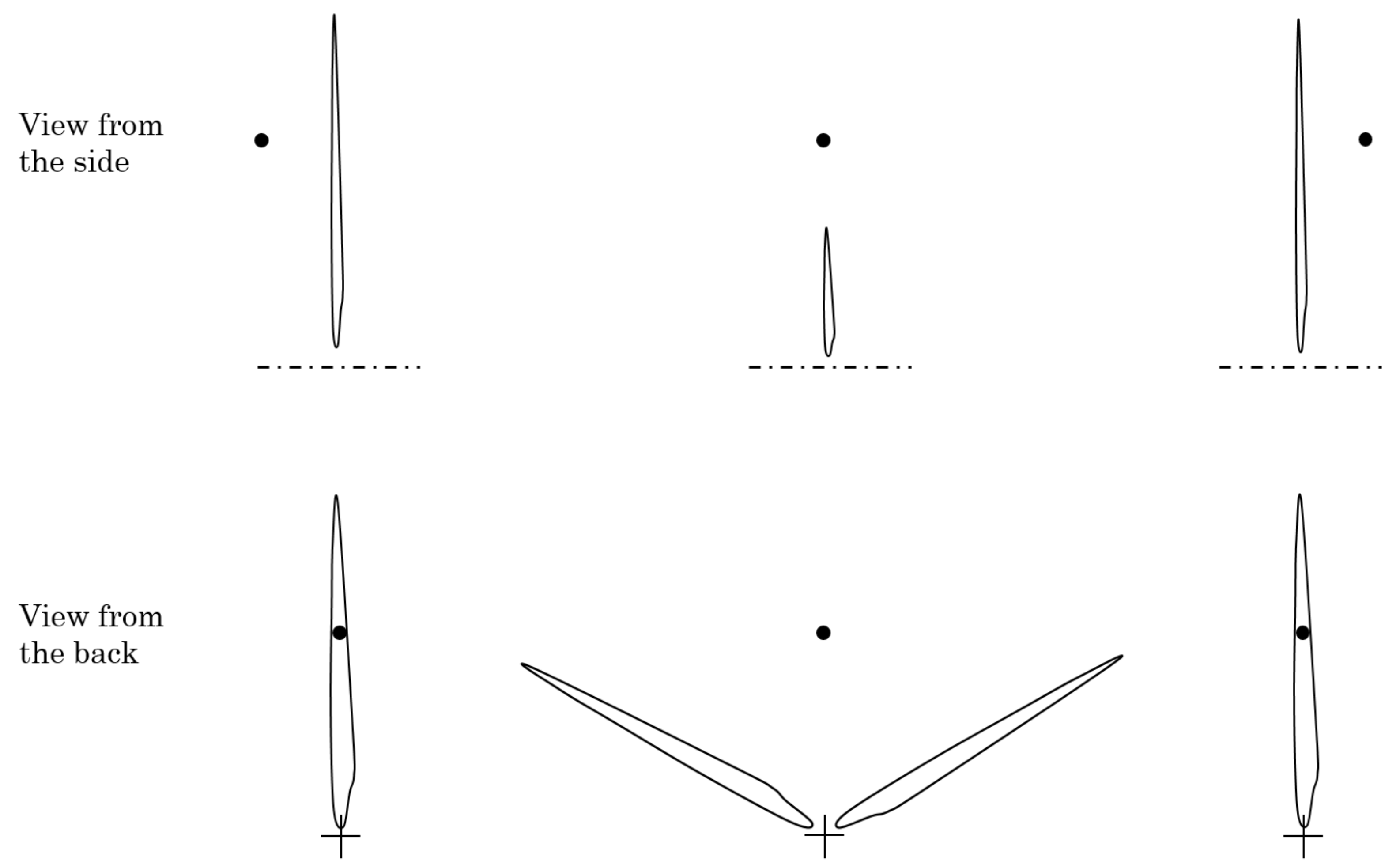

Figure 3: A scenario illustrating the relative positions of the blades and a bird as it flies across the rotorplane, midway between the blades. Note the large clearance as the bird passes through the danger zone.

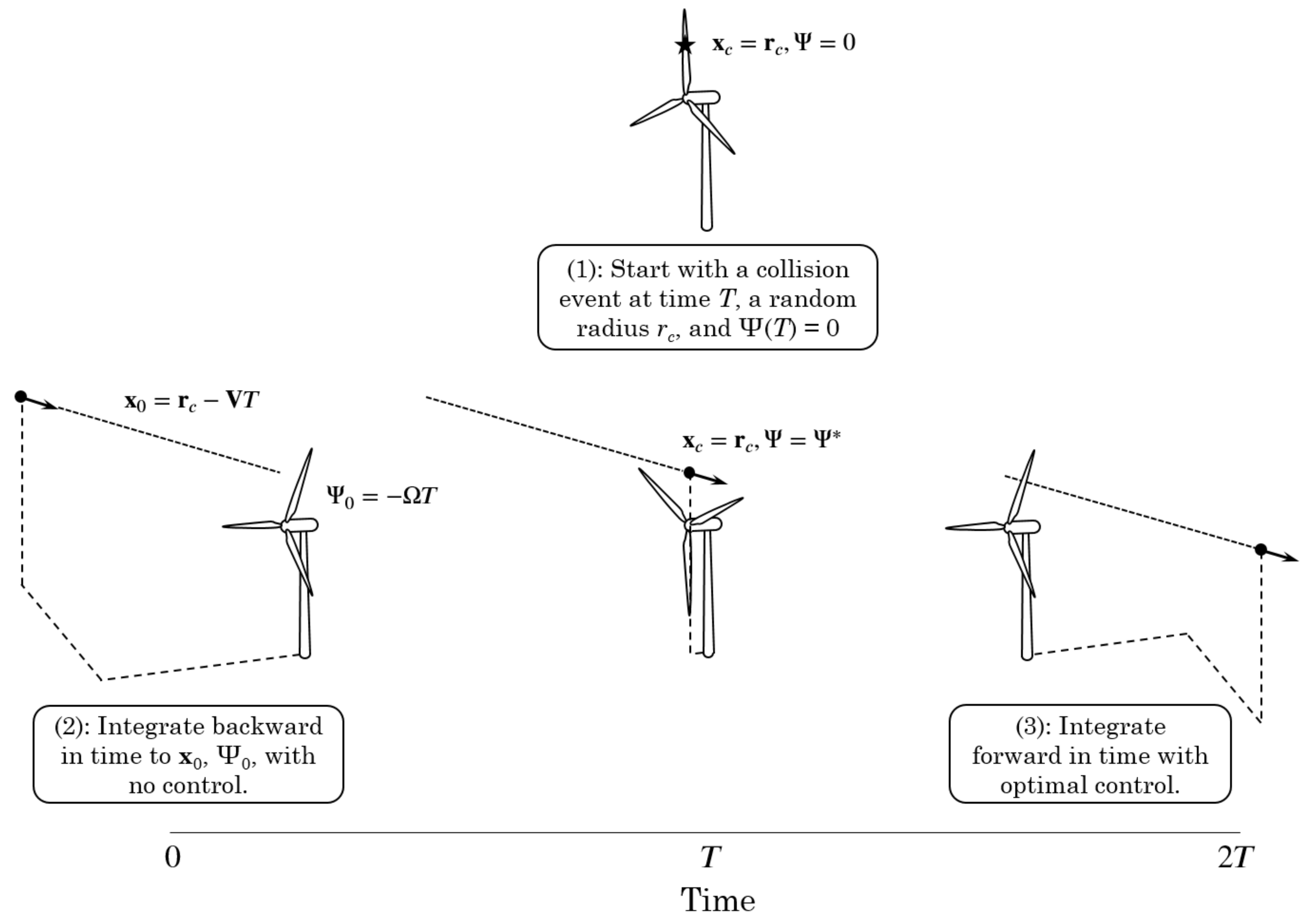

Figure 4: The procedure used to characterize the theoretical system performance. The analysis begins at time T, with a collision event. The dynamic equations are integrated back to time 0, with no torque control action. Then, the equations are integrated forward over a period $2T$, including collision-avoidance control.

A limited pre-project has been conducted to characterize the theoretical performance of the SKARV system, when the birds' flight paths are predictable. This provides a target against which the performance of future practical designs can be evaluated. Figure 4 illustrates the analysis procedure. The analysis begins with a collision, integrates backwards in time over a specified interval with no control action, and then integrates forwards with the optimal collision-avoidance control action.

Figure 5 shows two examples of a successfully avoided collision, using the DTU 10 MW Reference Wind Turbine. An *increase* in net shaft torque ΔQ is obtained by reducing the generator torque, while a *decrease* in net shaft torque is obtained by feathering the blades.

Analyses like those shown in Figure 5 were repeated in Monte Carlo fashion, randomizing the birds' flight paths and the rotor radius at which collision occurs. The probability of minimum clearance is shown in Figure 6: negative values indicate a collision. The SKARV system can be effective if the birds' trajectories can be predicted 5 seconds or more in advance; and the longer the prediction window, the less torque that is required to be effective.

Our future goal is to design a prototype system to be tested in the field.

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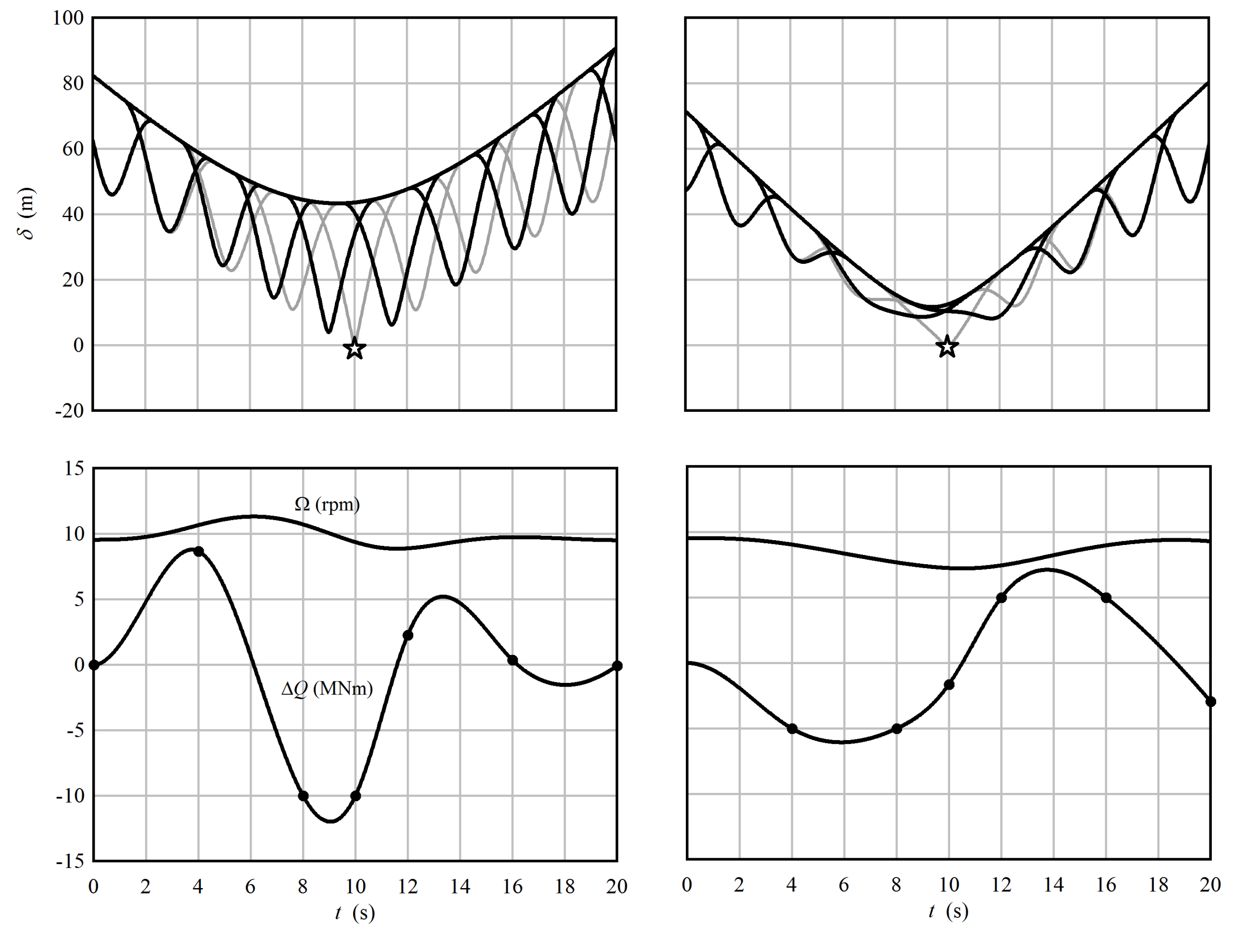

Figure 5: Two examples of optimal control histories. At top, the minimum distance to each of the three blades is plotted. Gray lines show the distances without control, culminating in a collision at t = 10 s. Black lines show the case where anti-collision control is active. At bottom, the optimal control histories are plotted. In the case at left, the rotor is accelerated, while at right, it is decelerated.

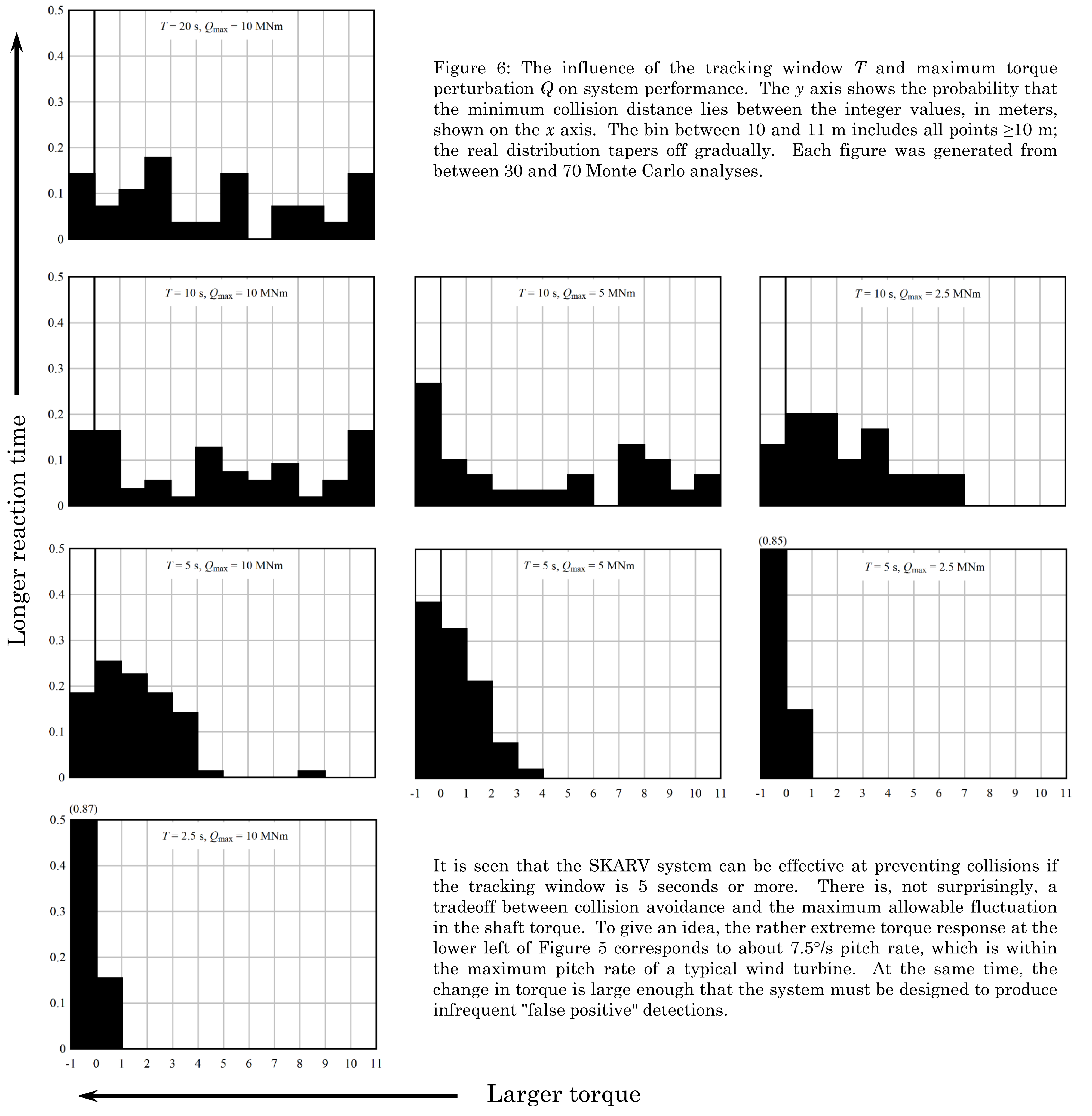

Figure 6: The influence of the tracking window T and maximum torque perturbation Q on system performance. The y axis shows the probability that the minimum collision distance lies between the integer values, in meters, shown on the x axis. The bin between 10 and 11 m includes all points ≥10 m; the real distribution tapers off gradually. Each figure was generated from between 30 and 70 Monte Carlo analyses.

It is seen that the SKARV system can be effective at preventing collisions if the tracking window is 5 seconds or more. There is, not surprisingly, a tradeoff between collision avoidance and the maximum allowable fluctuation in the shaft torque. To give an idea, the rather extreme torque response at the lower left of Figure 5 corresponds to about 7.5°/s pitch rate, which is within the maximum pitch rate of a typical wind turbine. At the same time, the change in torque is large enough that the system must be designed to produce infrequent "false positive" detections.