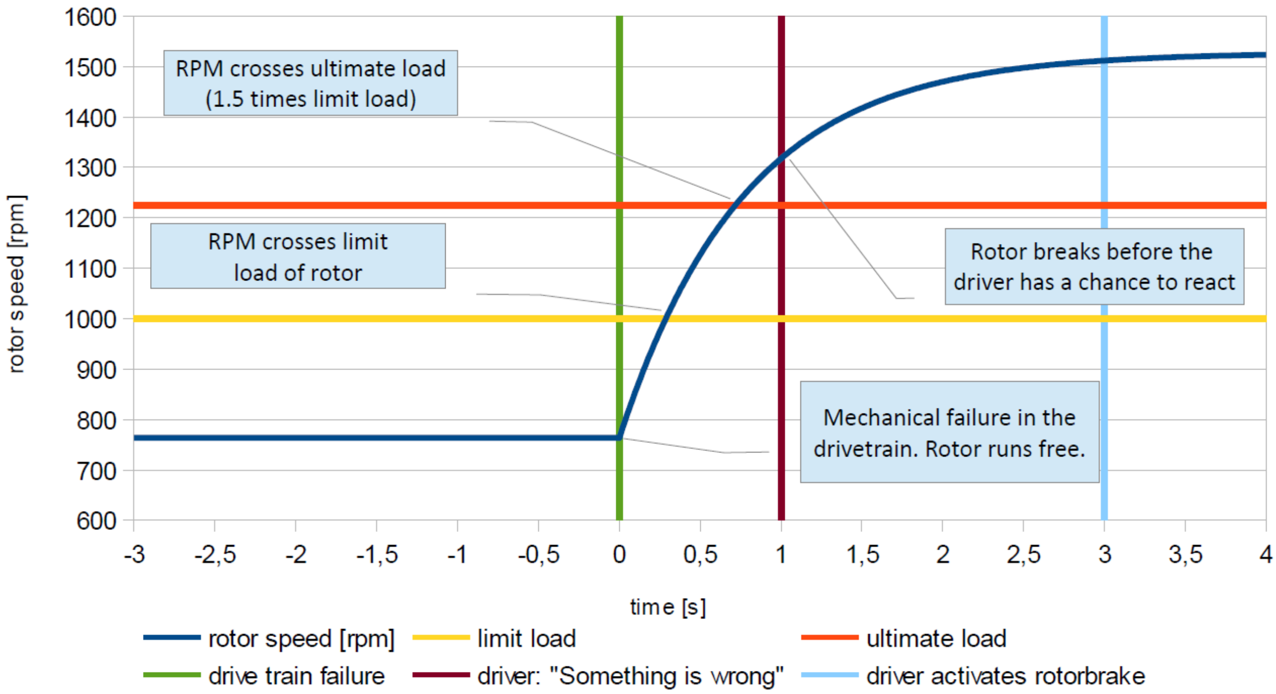
About the ROPS

Since the dawn of Racing Aeolus in 2007 the rules included a device that should prevent the rotor from overspeeding. Over the years this device has been heavily debated and only halfheartedly implemented. We, the Racing Aeolus committee, came to the conclusion that an automatic system limiting the rotor speed is very important and should be part of every car participating in the 2015 Racing Aeolus. On these pages we want to give an explanation why we think this way and provide some help to those teams who find the implementation of such a system challenging.

Why?

In 2013 we saw what happens when the connection of a rotor blade fails. Luckily nobody was seriously injured. But everybody realized the potential risk the event of a rotor failure poses. So we asked ourselves: “How can we prevent this from happening again?”

Firstly, make sure that the rotor blade connection is designed properly.
Every team must present their calculation of the rotor blade connection in the design report. Hereby we ensure that the rotor will not fail as long as the rotor speed is below the limit load speed.
But what happens if the rotor speed crosses the limit load speed? In normal operation the driver monitors the rotor speed and can apply the rotor break if the rotor speed gets too high. But is there any chance that the rotor accelerates so fast that the driver has no chance to apply the rotor brake in time? What happens if a part in the drivetrain fails? We did some calculations which resulted in the diagram below.



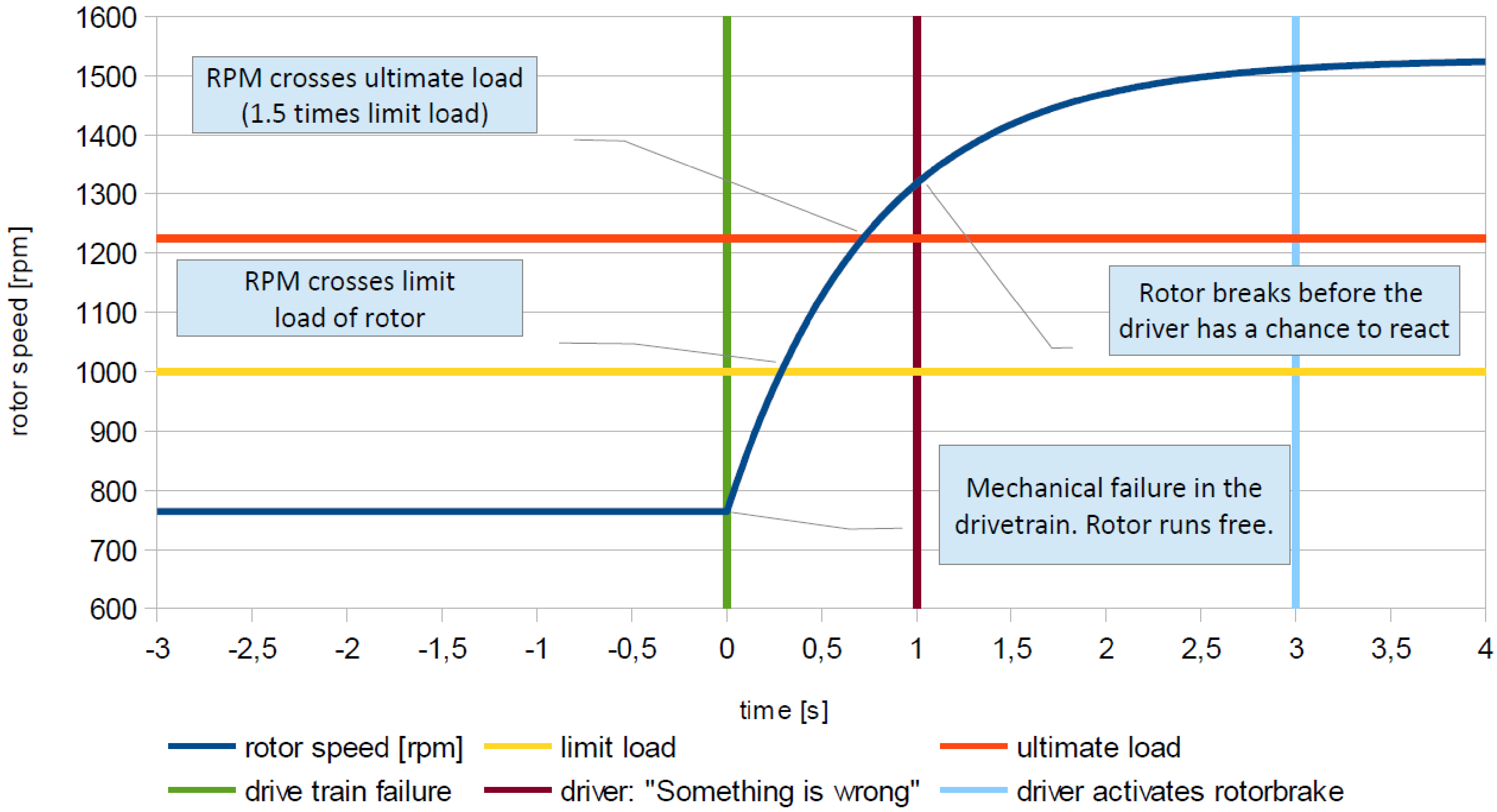
Rotor speed after a drivetrain failure, see attached spreadsheet for the calculations. Full page view at the end.

Evidently the driver has no chance to apply the rotor brake in time to prevent the rotor from crossing the ultimate load speed. If one studies the attached spreadsheet it will become clear that this case is only possible in high wind conditions. But since the event will take place in winds up to 18 m/s even higher inflow velocities can easily be achieved.
It takes just one second for the rotor to accelerate from well below the limit load speed to above the ultimate load speed. That is the time the driver needs to realize that there is some kind of problem. At that point the rotor connection will fail, if it didn't already do so.
This shows that only a fully automatic rotor overspeed protection system (ROPS) can prevent the rotor from breaking in case of a drive train failure.

How?

There are several ways to implement a ROPS. We'd like to highlight three of them to give you an idea how a ROPS can be done:

- Centrifugal brake
  - In a centrifugal brake the brake shoes rotate inside a cylinder and are kept from the walls by tension springs. If the rotational speed increases the centrifugal force will push the brake shoes against the wall and thereby limit the rotational speed. This is a very simple but effective ROPS and can be tuned to keep the rotor at a very precise speed.
  - These brakes can be bought off the shelf from a number of manufacturers like Suco (http://www.suco-tech.com/category.php?c=6)
- Electrical monitoring
  - An electrical system monitoring the rotor speed and automatically applying the rotor brake.
- Aerodynamic runaway speed design with automatic pitch
  - It is possible to design the rotor in such a way that makes it impossible for the rotor to cross a certain speed because it's rotational resistance is as great as the force driving the rotor. If this speed is below the limit load speed, the rotor can not cross the limit load speed even in a runaway situation. Since the runaway speed depends on the inflow velocity there has to be an automatic pitch to adjust the runaway TSR for high inflow velocities.



rotor speed [rpm]
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
-3
-2,5
-2
-1,5
-1
-0,5
0
0,5
1
1,5
2
2,5
3
3,5
4
time [s]
RPM crosses ultimate load (1.5 times limit load)
RPM crosses limit load of rotor
Rotor breaks before the driver has a chance to react
Mechanical failure in the drivetrain. Rotor runs free.
rotor speed [rpm]
limit load
ultimate load
drive train failure
driver: "Something is wrong"
driver activates rotorbrake