KUHN Electronics
INNOVATIVE FARMING

THE BENEFITS OF ELECTRIFICATION:

APPLICATION ON A ROTARY RAKE

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Summary

- Current Kuhn rotary rake range
- Why a rake electrification ?
- Electric drive architecture
- eGA equipment
- eGA field tests
- eGA results after season tests
- Comparison GA13131 vs. eGA
- Lessons learned
- Benefits of electrification

Kuhn rotary rake range

- KUHN GA rotary rake range:
  - 26 models from 1 to 4 rotors
  - Working width: 3.2m (10.5') to 15m (49.3')
  - 3-pt mounted or trailed
  - Raking height adjustment: mechanically on the machine or hydraulically from the cab
  - Power distribution: mechanically (PTO) or hydraulically (only for the 4-rotor rakes)
  - Rotor speed depends on tractor engine speed

- What is a rotary rake used for?
  - Hay, silage or straw harvesting
  - Form even and fluffy windrows to be processed by baler / chopper / loader
  - Raking is part of the dairy/beef/biogas production chain
  - Quality of work is key

KUHN 4-rotor rotary rakes

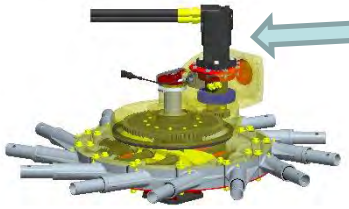
GA13131

- **Currently in production**

- Max. working width: 12.5 m (41’)
- Max. windrow width: 2.4m (7’10’’)

- Controlled by a machine ECU via ISOBUS
  - Easy to understand and operate
  - Adjustment
    - Windrow width
    - Working width
  - Folding/Unfolding Movement
  - Headland management
    - One key press to execute half turn sequence
  - Individual control of each rake during work
    - Raking height,…
  - ..

Hydraulic power drive



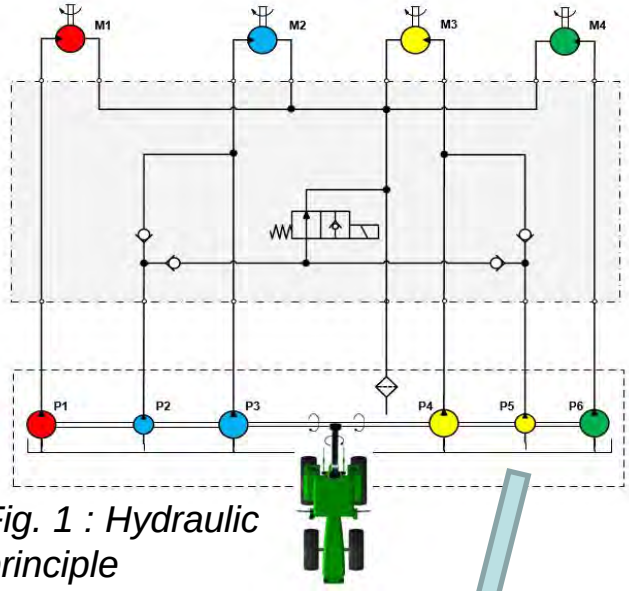


Fig. 1 : Hydraulic principle

- PTO speed input:
  - Gearbox 1000 rpm (optional: 750 rpm)
- Rotor speed on 4 hydraulic motors:
  - 51 rpm
  - Able to boost to 61 rpm (+ 20% on the 2 front rotors with 2 additional pumps)
  - Rotors speeds depend on tractor engine speed
- Torque limited by pressure relief valve (smooth):
  - Set to 200 bar (2900 psi)
  - Max. drive power : 4 x 20 kW
  - Very limited maintenance required
- Quiet drive

Why a rake electrification ? eGA

- **Next step after the hydraulic drive ! ➔ measurements, controls, efficiency…**
- Technical goals:
  - Analysis of rotor speed adaptation in different forage conditions
    - Hay: very light, but long & bulky
    - Silage: heavy, but short forage
    - Straw: short, stiff, light forage
  - Each rotor speed can be set individually
  - Fuel savings through better system efficiency
  - Rotor speed independent from tractor engine speed
  - Improve rake capabilities for such high productivity machines
  - Improve power distribution to rotors (cables vs. pipes/hoses or drivelines & gearboxes)
- Other goals:
  - Improve skills and know-how in High Voltage
  - Select a product rapidly adaptable with a good reliability
  - Participation in electrification projects with other manufacturers and AEF

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Electric drive architecture

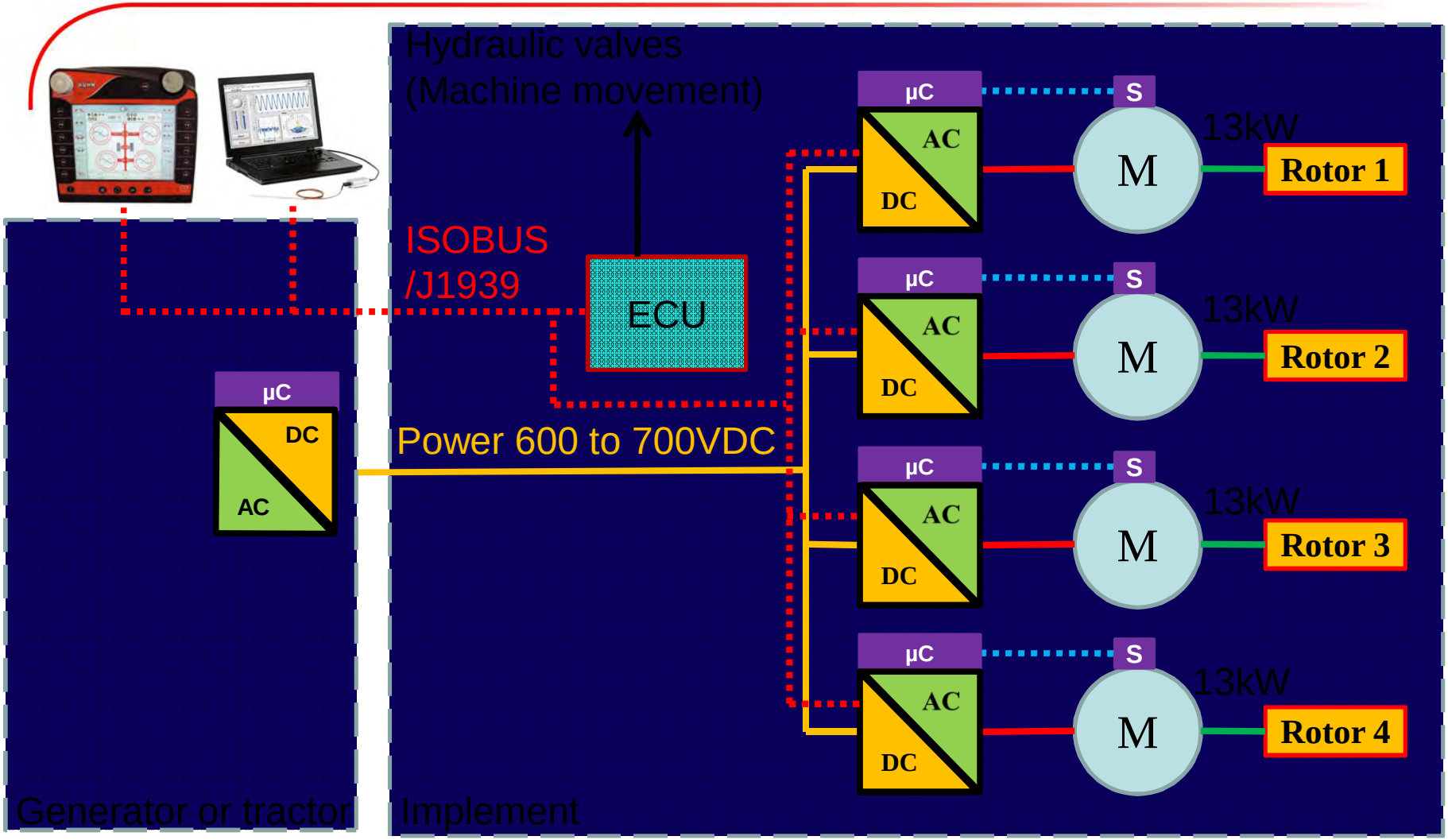


Fig. 2 : Global electric architecture

Electric drive architecture

Motor type :

Motor type	DC	Induction	Synchronous
Dimension / weight	High	Medium	Low
IP level	Low	Medium	High
Efficiency	Low	Medium	High
Inverter complexity	Low	Medium	High

Motor cooling :

Cooling	Nat. Cond.	Forced conv.	Fluid cooling
Dimension / weight	High	Medium	Low
Clogging risk	Low	High	Medium
Complexity	Low	Low	High

Motor mechanical coupling :

Coupling type	Direct drive	Belt (+ gearbox)	Gearbox (on machine)
Dimension / weight	High	Low	Low
Motor price	High	Low	Low
Efficiency	High	Medium	Medium
Integration complexity	High	Low	Medium
Availability	Low	High	/

→ Best compromise (weight, complexity, availability) :

- **Forced air cooled synchronous motor with belt**

Electric drive architecture

Competitor motor integration:

	Motor type	Cooling	Coupling
Fendt	Synchronous	Natural	Direct drive
Claas			Gearbox
Pöttinger		Forced	Gearbox + belt
Kuhn			

Source: https://www.agroinform.hu/gepeszet/fendt-es-agco-dijak-es-ujdonsagok-25139-001

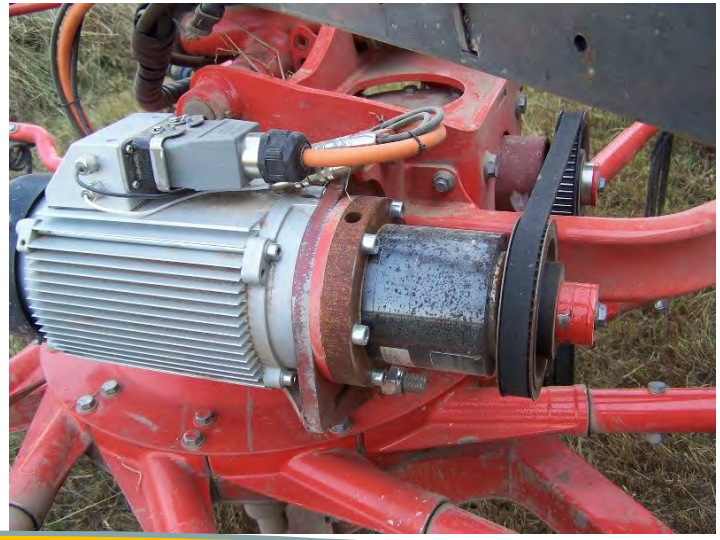
Source: Electrification and Hybridization for CLAAS Tractor, 03/12/2016, A.HAMMAR

Source: AEF

eGA equipment

- Electrical box replaces the tank of the hydraulic machine
- 4 water-cooled inverters
- Heat exchanger

- 13 kW motor at 5000 rpm
- Air cooled motors
- Reducer: coaxial + rotor: i=100/1
- Belt & pulley
- Motor + reducer weight: 30kg
- Waterproof motor IP69K



Adaptations for testing purposes only
(not final integration on machine)

eGA field tests

PP50 + eGA

- Up to 50kw power
- Front PTO Drive
- Compatibility with any tractor
- 17 ha raked (drought in France)

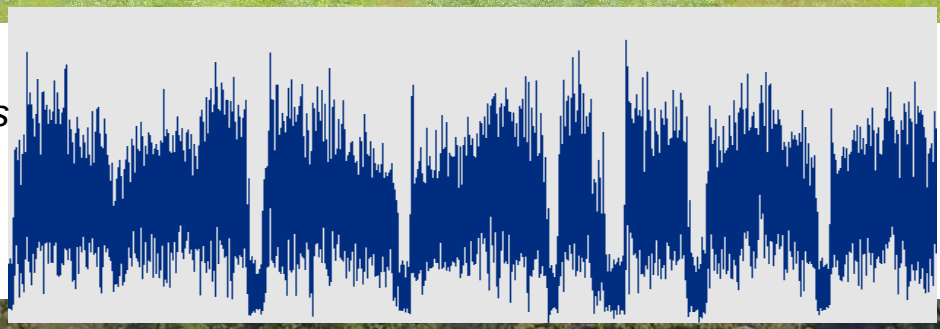
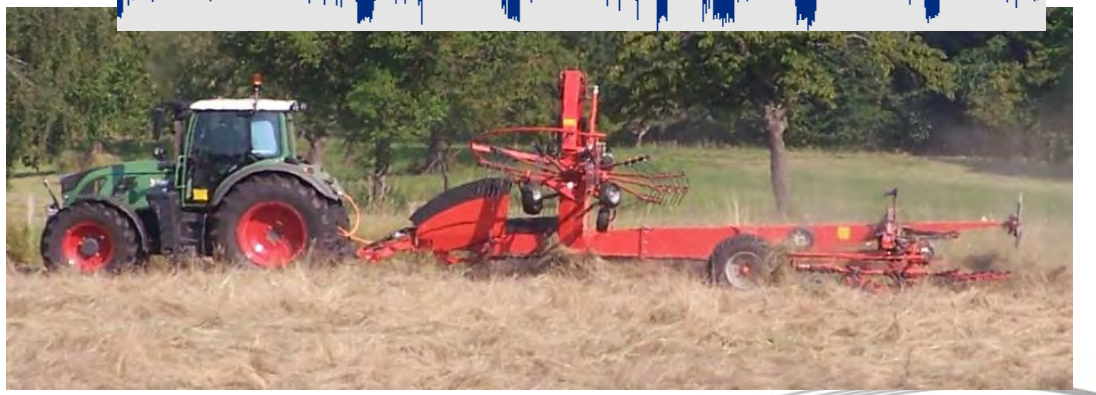


Fig. 3 : Instantaneous Power

Fendt X Concept + eGA

- 35 ha (90 acres) raked
- Rotor load/overload tests
- Implement input power comparison:

  KUHN GA13131 vs. eGA
- Measurements of different parameters (voltage, amperage, torque…): Fig 3



eGA field tests

eGA results after season tests

- Good regularity of the rotor speed (speed control loop)
- Less noise than the current hydraulic KUHN GA13131
- In cab LabView control panel (fig. 5)
  - Real-time overview of the parameters and measurements
  - Rake parameters easily adjustable
  - Measurements logging (see inverter data on fig. 4)
- To be further reviewed :
  - Air cooling fan obstruction (no dangerous temperature elevation observed in 2015/2016)
  - Temperature of the speed reducer in severe conditions

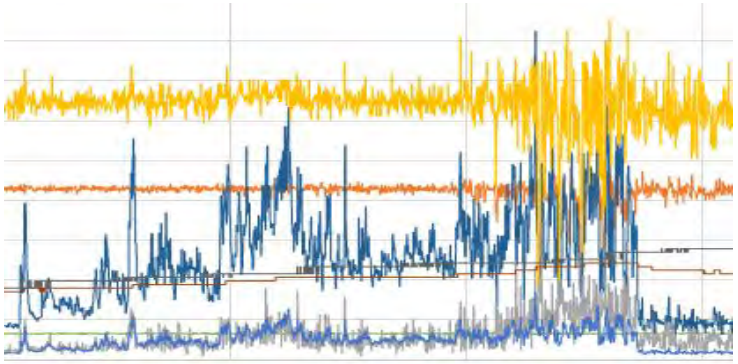


Fig. 4 : Inverter data

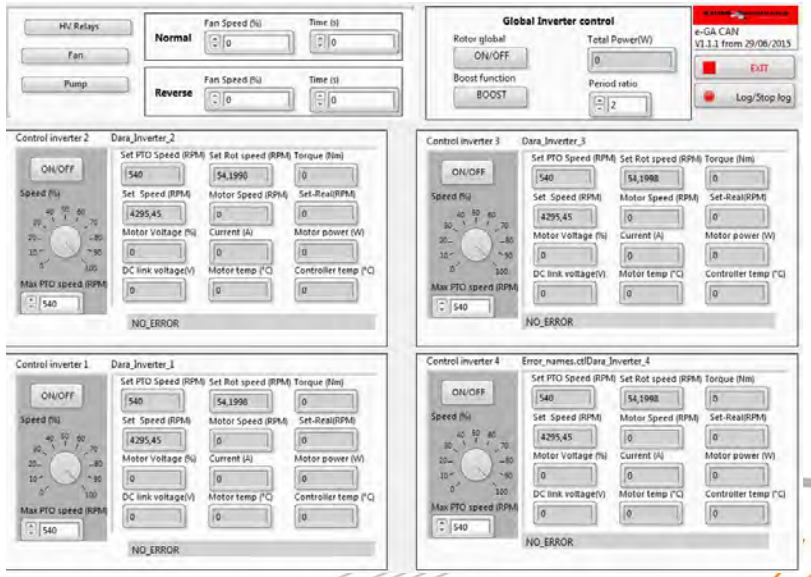
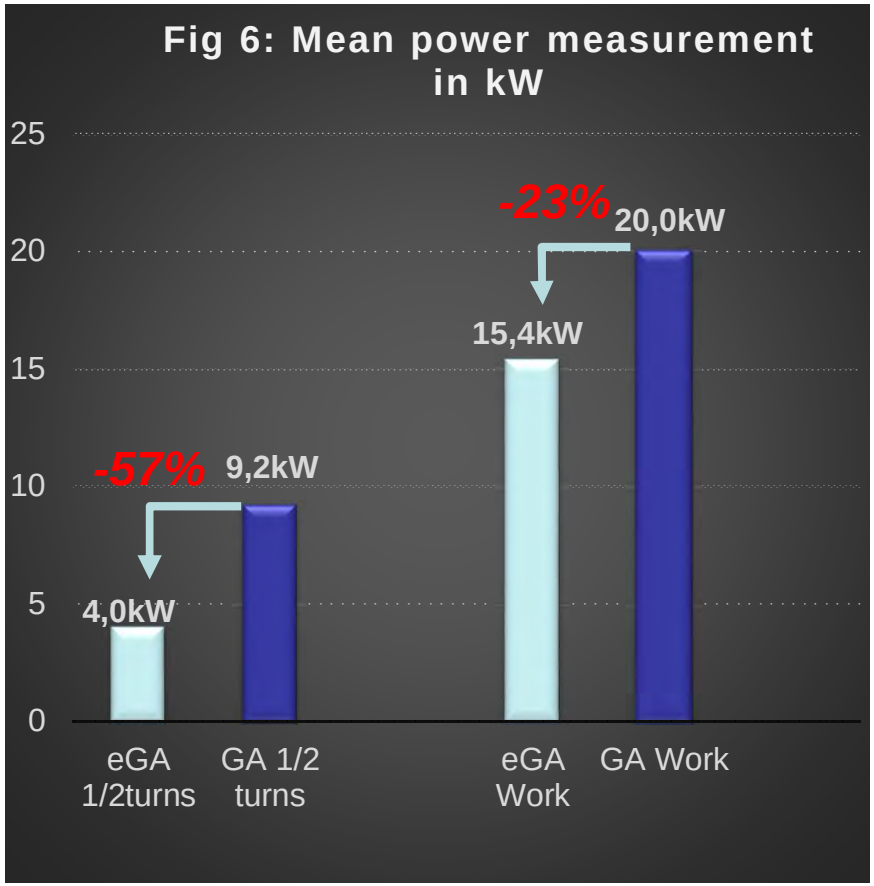
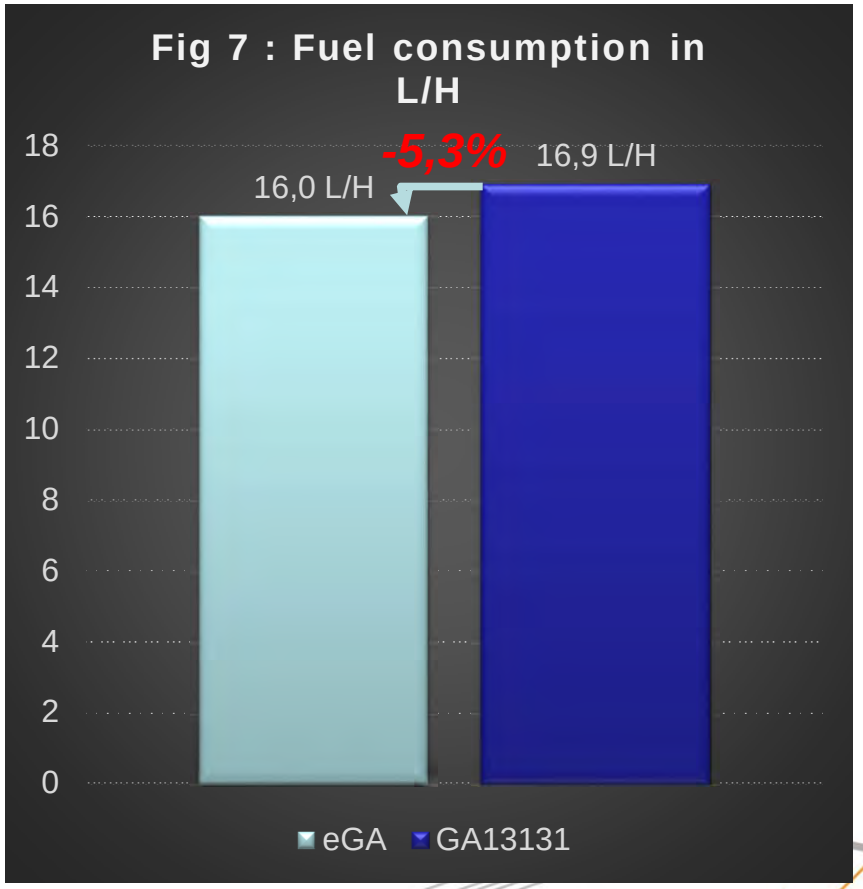


Fig. 5: PC control panel

Comparison KUHN GA13131 vs. eGA

- Power comparison between electrical and hydraulic rakes in identical conditions
  - 1 field, 20Ha, flat field, low forage quantities, sept. 2015





Lessons learned

- First trials show a great power reduction on the machine but with limited impact on fuel savings
  - To be confirmed during next season tests
- Stopping the rotation of the rotors at the end of the fields will not provide large fuel savings.
- Technical experiences about High Voltage :
  - Starting and peak current inputs for the global system design (AEF discussion)
  - Capacity balancing issues between machine and generator on DC systems
  - Increasing skill and knowledge in this new technology within our company
- Potential new rake functions :
  - Stopping the rotation of the rotors when travelling over existing windrows (safety, no disturbance of windrows)
  - Power and torque limitation
  - Adjustable speed or raking height depending on working speed, forage type, torque levels
- Cost studies :
  - +100% extra costs for prototype machine
  - Estimated +20% for production machine

Benefits of electrification

- Comfort enhancement: simplification of many operations for the driver.
- Machine feeling and control: more information can be displayed to the driver.
- Fuel savings due to the optimization of the tractor engine operating point.
- Precise speed and position automation.
- High efficiency.
- Easy connection to the tractor.
- New potential design and functions.
- Less maintenance.
- Easy load protection (speed/torque limiting).

THANK YOU FOR YOUR ATTENTION