Electrified Utility Tractor

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Abstract

Although the diesel engine will most probably remain the dominating power source for large scale tractors in the years to come, battery electric systems are showing a high potential for emission reduction and energy efficiency improvements in smaller utility tractors. There is an opportunity for new ideas and fresh thinking in agriculture following the progress of electric drive systems and battery technology.

Yet another aspect comes into play creating a supporting environment for electric machinery in agriculture: Many farmers - especially in Germany - have installed large scale solar power and biogas plants providing a perfect infrastructure for own on farm green energy use, especially as feeding electricity into the grid becomes less and less attractive.

The Fendt e100 battery electric utility tractor is the next step in a journey to create sustainable and professional farm machinery. Its heart is a 100 kWh high performance battery and a 50 kW rated power electric motor. New approaches for energy and temperature management go side by side with practical charging solutions and electric implement interfaces based on Isobus communication and the AEF standards.

Challenges

Since 2001 AGCO has been working on a broad range of electrification projects to build knowledge and prepare technology in this discipline. The starting point was a diesel-electric power drive project (“MELA”), followed by the E-RoGator diesel-electric drive sprayer in 2010, the Fendt X Concept tractor in 2013 and lately the electric driven rake Fendt Former 12555X in 2015. Electrical drivetrain components are available and meanwhile have become state of the art. The same applies to the electric high voltage safety systems, power electronics, brake choppers and other components.

The challenge for a fully electric tractor is the energy storage - in this case a battery - which has to be compact and light enough to run a smaller tractor up to five working hours with one charge under its typical load spectrum. It also has to deliver reliability for about up to 10,000
working hours within ten years as expected primary use life cycle estimation. The invest and overall operating costs have to be attractive for markets to reach significant volume and yield the benefits related to lower emissions and energy consumption in agriculture and also municipal use.

**Tractor Concept**

In the initial project phases various concepts were evaluated and some general decisions were made as follows:

- The rated power of the machine should be below 60 kW, expanding the actual Fendt product range.
- Customers should be able to use their existing conventional implements as well as electrified ones where beneficial and available.
- The charging technology needs to be practical like e.g. supporting a CEE (Commission on the Rules for the Approval of the Electrical Equipment) standard power outlet.
- The system voltage should be within the agreed AEF standard of 700 V DC +/- 10 %.

Some modules of the battery tractor share a common platform with the Fendt 200 P series (e.g. cab, hydraulics, transmission) perfectly supporting typical target applications: on a farm as a multipurpose machine and in cities as the flexible utility tractor for municipal use. By using a Fendt Vario gearbox for the driveline all components of the PTO, the hydraulics and other auxiliary drives can remain unchanged. Instead of a diesel engine, a 50 kW electric motor delivers superior torque and dynamic response with low noise and zero emission. Battery, charging device, power electronics with integrated brake chopper and the high voltage coupling modules were all designed and packaged to fit under the hood with no compromise in visibility and styling.

Most cooling components are installed in front of the battery. An innovative heat pump system delivers all required fluid temperatures. The power distribution unit (PDU), which interlinks the high voltage components, is fixed next to the CCS Type 2 (Combined Charging System) connector on the left vehicle side. A DC/DC converter powers the 12 V circuit and charges a small 12 V battery used to buffer this low voltage circuit and support the startup process of all electronic systems. Two high voltage connectors and Isobus interfaces are installed on the tractor: one at the front and one at the rear.
Developing a battery, which meets the tough requirements of a mobile working machine as a main power source, was obviously one of the biggest challenges of the project. The vehicle specifications require a small and light battery, fast charging times, standard connectors, voltage level according to AEF Standard, an energy capacity of min 90 kWh and a high number of reliable charging cycles. On top of that, it has to deliver high electrical current in all relevant ambient temperature conditions.

As result a battery has been developed, which works at a voltage of 650 V, storing 100 kWh of electrical energy at a volume of 320 l and a weight of 590 kg. It is built out of Li-Ion 18650 cells. These are connected in a 180 (serial) times 46 (parallel) package. With this concept and the cell type, the costs could be brought down to an acceptable level while delivering the required performance values. The accumulator includes a battery management system (BMS), a safety concept and sophisticated temperature controls.

**Battery**

Fig. 1: Fendt e100 Vario system overview
Thermo Management
A typical Li-Ion cell ideally needs to operate in a temperature range between 15 and 25 °C to guarantee a long battery lifetime and reach high numbers of charging cycles. An innovative thermo management has been developed to actively cool and heat the system. The switchable heat pump efficiently supplies the tractor with cold or warm fluids as needed. It is also designed to recuperate energy from the installed heat exchangers to further improve energy efficiency.

Energy Management
A smart energy management supports the driver while working. The system permanently monitors energy flow, state of charge and remaining operating time for the current consumption level. With the aid of a specially developed smart device application, the operator is able to plan his working day and needed energy resources in a very simple way.
Charging

Perfectly charging a Li-Ion battery is a complex topic. Wrong charging can destroy a battery within a few cycles. Charging at too low or too high temperatures will cause a loss of battery lifetime. Furthermore the right charging current for the specific needs of each customer and operating schedule have to be identified. This clearly shows the importance of an elaborate charging management. The Fendt e100 offers various charging modes and powers:

- One phase power AC socket: 16 A @ 230 V (3.6 kW charging)
- Three phase AC socket: 32 A @ 400 V (22 kW charging)
- DC Power: 200 A @ 700 V (140 kW charging)

A suitable charging hardware and software is installed to handle these charging modes. The Fendt e100 uses the CCS Type 2 standard connector. The battery can be charged within 40 minutes at 200 A @ 700 V DC (quick charging station required) or within 5 hours at 32 A @ 400 V plugged into the CEE standard connector, available on nearly any farm.

Benefits

The Fendt e100 is a fully electric utility tractor and has been designed to suit farming and forestry applications as well as municipal operations. A dedicated 100 kWh high performance battery pack was developed as well as an energy efficient thermo-management using a heat pump system.
The concept offers the following major benefits:

- Zero local emissions and less noise, perfect for municipal or on-farm operations.
- Reduced energy costs. Ready to use and store energy produced on the farm.
- Less maintenance and fluids, no exhaust after treatment systems.
- Less CO₂ emissions, down to zero when using renewable sources.
- Highly efficient driveline with energy recuperation.
- Superior driving dynamics and strong torque from zero rpm.
- Full compatibility to conventional implements while also providing electric interfaces.