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Hybrid systems for Agricultural Engineering

Many electric driven agricultural machines have been presented in the recent years. Their advantages, apart from exact controllability, are speed variability and overload capability. To utilize the advantage of variable speed some more possibilities are available. It has to be considered, that the architecture of the drive-train determines the realizable functions. This paper considers selected hybrid-structures and functions on the example of a tractor and a drive on a manure spreader. Furthermore the potential of electric drives from the view of Austrian manufacturers of agricultural machinery is reported.

Keywords
Hybrid, electric drive, power-split, survey

Abstract
Landtechnik 68(1), 2013, pp. 22–25, 3 figures, 1 table, 20 references

In consequence of the high energy density of diesel-fuel it is assumed that the diesel-engine will be used dominantly in the agricultural business during the next decades. Comparisons with regard to energy density can be found e.g. in [1]. The diesel's energy density is better by a factor 50–100 than those of accumulators. The lately presented machines and implements with electric power-drive are mainly pure electrified or in serial hybrid-structure [2–7].

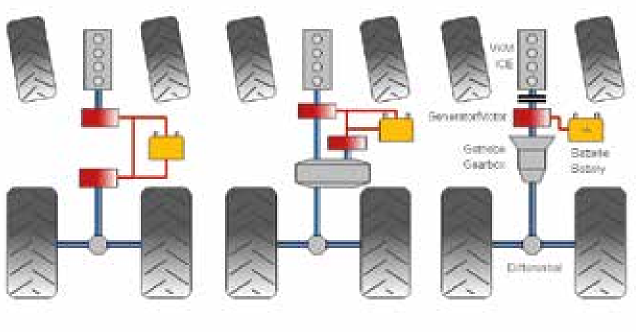
In those system-architectures the whole power delivered by the diesel-engine is first transformed into electric power by a generator and then re-transformed into mechanical movement by an electric motor. Control-units and, if necessary, storage devices are installed between. The amount of transformed power has to be considered carefully with respect to the losses occurred during transformation. For certain applications power-split or parallel hybrid-structures are useful, as described e.g. in [8] and [9] (**Figure 1**).

Agro-Hybrid functions

Literature from the automotive-sector refers basically to the traction drive-train. Agricultural machines have furthermore a huge variety of functional drives. For instance a tractor equipped with a generator could realize the functions illustrated in **Figure 2**.

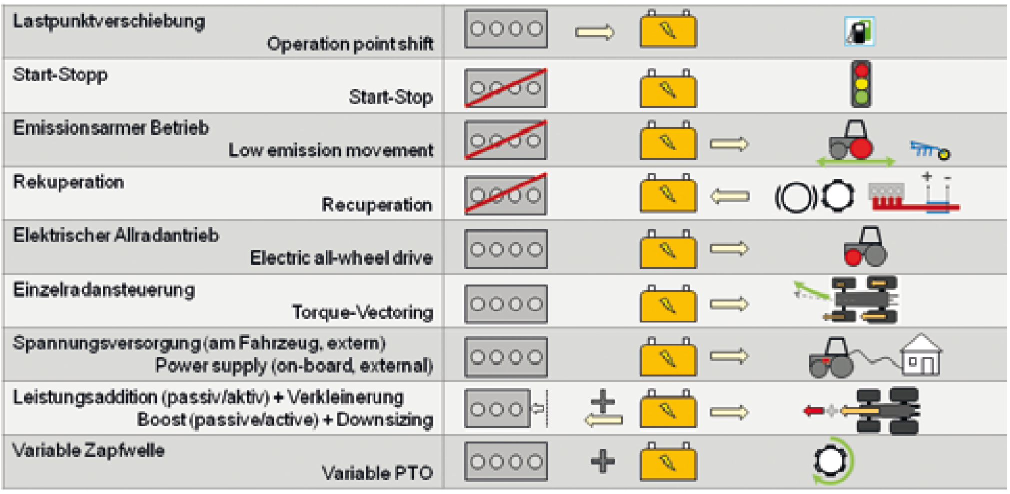
The specific fuel consumption of a diesel-engine in part-load operation is relatively high. When the engine is operated with torque reserves, these reserves can be used to power a generator. For this purpose a battery-management-system is mandatory [10]. The advantage gained by the reduction of the specific fuel-consumption must overcome the losses raised by the energy-transformation. At vehicle stop the internal combustion engine (ICE) could be turned off, if the operating temperatures of the coolant, exhaust gases treatment system etc. have been reached. A pure electric traction drive might be beneficial for urban transportation or for short cycle movements; hence the exhaust emissions and the noise exposure can be reduced. The potential for recuperation is limited in agricultural machinery [9]. In reference to the construction site machinery [8] the rotating machine parts on implements or alternating hydrostatic loads can be used for energy recovery (implement powertrain, PTO-shaft, cylinders). For small electric loads the utilization of exhaust-gas thermal energy can be considered. The tractor's front axle can be driven electrically. In this case the power distribution and the front axle-construction could be simplified. The mechanical differential can be replaced by the electric driven front wheels. The lead can be eliminated by the individual speed of each single tire with respect to the steer-

Fig. 1



Basic hybrid-structures for a rear axle drive (serial, power-split, parallel)

Fig. 2



Feasible functions on a hybrid-tractor

ing angle and further parameters. Advantages can be derived from [12]. Then the wheels need to be individually controlled [13]. With a variable or partly variable PTO the working speed on rigid coupled implement-drives can be controlled independently from the speed of the ICE.

Agro-Hybrid structures

In general the following structures can be appropriate for functional- or traction-drives on agricultural systems (self propelled machine or tractor-implement-system):

- electrification
- serial agro-hybrid
- power-split agro-hybrid
- paralley agro-hybrid

Self propelled machines and tractor-implement combinations have to be distinguished. Self propelled machines are basically closed systems with functional assemblies as harvester headers or combines' cutterbars being seldom changed in normal operation. The interface-problems are therefore solved relatively simple. Hereinafter a tractor and a manure spreader with variable feed drive are considered as an example.

The functions that could be realized are depending on the agro-hybrid-structure.

For full variable chain feed drive including reverse direction of rotation (-n...0...+n) the serial structure is prefered (**Figure 3**, a). The feed power is provided electrically, which requires a multiple transformation of the whole power needed for the feed drive. It can be generated on the tractor, an PTO-driven power pack or on the implement itself [7].

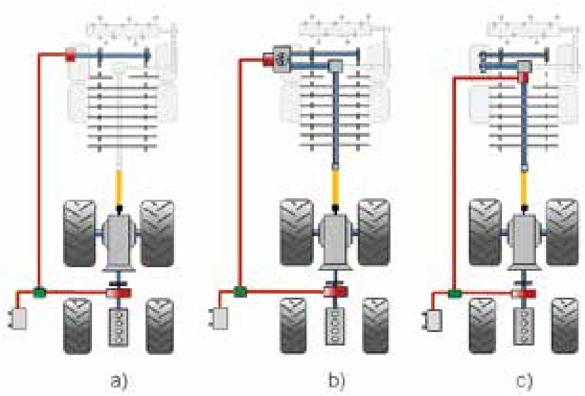
Power-split systems can be beneficial for applications that need variable rotational speed within a certain range. The range-variability ($n \pm \Delta n$) can be realized by speed superposition with planetary gears. The major power is transferred conventionally e.g. by mechanical PTO-shaft. An electric motor overlaps the provided power from the PTO and covers the variable power demand (**Figure 3**, b). Based on the limited range of speed-variability the amount of variable electric power is smaller than in the serial structure. Losses due to power conversion can be reduced. Alternatively the superposition can be realized by hydraulics.

If power-peaks shall be covered then the use of a parallel structure (power addition) could be considered (**Figure 3**, c). Power boost is possible by the electric drives ($P + \Delta P$). A support for acceleration of machine parts is feasible. For power boost also hydraulic elements are available [14–16].

The hybridization can be applied on following drives, e.g.:

- chain feed drive
- spreader discs
- traction drive
- speader drums

Fig. 3



Manure spreader with chain feed drive in different agro-hybrid-structures (serial, power-split, parallel)

Table 1

Hybrid functions according to hybrid structure

Funktion *Function*	**Seriell** *Serial*	**Leistungs-verzweigt** *Power-split*	**Parallel** *Parallel*
Variabler Kratzbodenvorschub *Variable chain-feed drive*	x	x	
Variable Streubreite *Variable spreading width*	x	(x)	
Zugkraftunterstützung *Supported traction force*	x	(x)	
Variable Walzendrehzahl *Variable drum-speed*	x	(x)	
Unterstützung bei Kurvenfahrt *Torque vector control*	x	(x)	
Boost *Boost*	x	x	x
Instationärausgleich *Dynamic load compensation*	x	x	x

Table 1 shows that the hybrid-structure and the corresponding electric power requirements are depending on the requested functionality.

The thermal loads resulting from the losses during repeated power-transformation take on an important role and have to be considered in the machine conception [17, 18]. They can be kept small, e.g. with minor power, to possibly skip a separate cooling-system or utilize air-cooling only.

Potential of electric drives in agricultural machinery

Possible applications and their power requirements were collected in two surveys among manufacturers of agricultural machinery [19; 20]. It was assessed that power values of drives on implements are typically 50–60 kW. The use appears to be promising in applications where infinitely variable hydrostatic drives can be replaced by electric ones (e.g. at traction drives on large self-propelled harvesters) or where processes can be automated to increase the productivity. The availability of electric power delivered by the tractor is expected in the next 5 to 10 years. A total substitution of hydraulic or mechanic drives by electric ones is not expected.

The identification of beneficial applications has to be considered carefully with respect to customer acceptance.

Conclusions

The benefits of electric drives have been demonstrated in many projects. The diesel-fuel will remain as the primary energy source thanks to its high energy density. The electricity will be generated by a diesel-driven electric machine. Electric drives will become more important due to the increase of efficiency and functional/productivity extension. The broad introduction of electric driven agricultural machinery is expected in the next 5 to 10 years.

The structure of the drivetrain depends on the required functionality. Serial, power-split or parallel systems favor different functions, as shown. System architectures with small variable (electric of hydraulic) power-share might be beneficial when focusing on little thermal losses.

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