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Supplementary electricity storage in agricultural machinery electric motors

Farm machinery with electric drive trains the possibility of buffer storage of electric energy must be considered so that reserves are available for supporting the diesel engine when loads are altered. In principle flywheel storage, batteries and blocking layer condensers are suitable for this. The storage, integrated in the drive system, should be capable of producing supplementary energy for the driving power within a relatively short period during vehicle acceleration. Main criterion is therefore the performance density of the storage and thus the blocking layer condenser is preferred. Three possible applications on the diesel-electric powered vehicle were investigated.

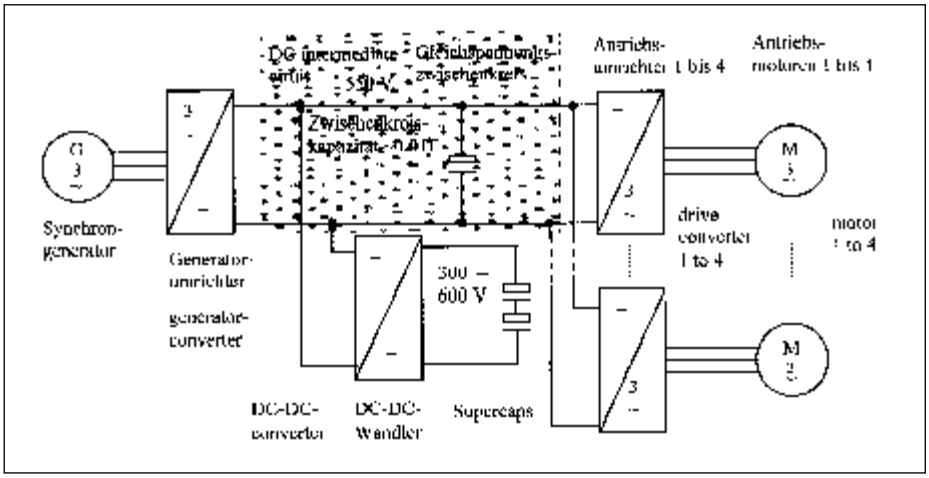

Fig. 1: Coupling the ultracap's on the intermediate circuit

In farm vehicles with electrical drive trains the possibility must be considered for providing buffer storage of electrical energy as a certain reserve for the support of the diesel engine during load alterations. In principle flywheel storage, batteries and blocking layer condensers are suitable for this. The high costs of flywheel storage (special material, mechanical coupling) means this is not suitable in farm vehicles. Comparing electricity storage facilities involves assessing weight-related energy content in relationship to weight-related performance. The storage facility, for integration in the drive system, was sought under the main aspect of being able to produce supplementary energy for vehicle drive within a relatively short time during vehicle acceleration. Main criterion is therefore the performance density of the storage. A higher amount of stored energy enables the additional function of being able to switch off the diesel completely when power requirements are low. There are three possible applications for the stored energy:

- Making available additional energy during acceleration phase
- Taking over energy delivery to the drive during diesel engine acceleration
- Delivering energy during diesel engine starting procedure.

The three applications with required stored energy are given in *table 1*.

Table 1: Case of application and energy required

Application	Energy
Vehicle acceleration	min 300 kWs
Energy during diesel acceleration	70 kWs
Starting procedure	< 3 kWs

The role of an energy store on the vehicle

A DC-DC converter is required to couple a blocking layer condenser, with widely varying voltage output, to an intermediate circuit driven with relatively constant voltage. *Figure 1* shows the attachment of the blocking layer condenser to the intermediate circuit.

Possible application variants

Boosting during acceleration phase
If several condensers are activated in parallel total capacity is then the sum of the individual capacities

$$C_{ges} = C_1 + C_2 + C_3 + ... + C_n$$

With this, very large capacities with high voltage can be achieved. If there is enough room on the vehicle and the additional weight is no problem, a boost function can be realised through additional electricity storage. In *figure 2* the require total capacity of the condenser block is shown in relationship to the power (P_{boost}) which must enter the in-

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Keywords

Blocking layer condenser, diesel electric drive train, energy storages, DC-DC-converter, intermediate circuit

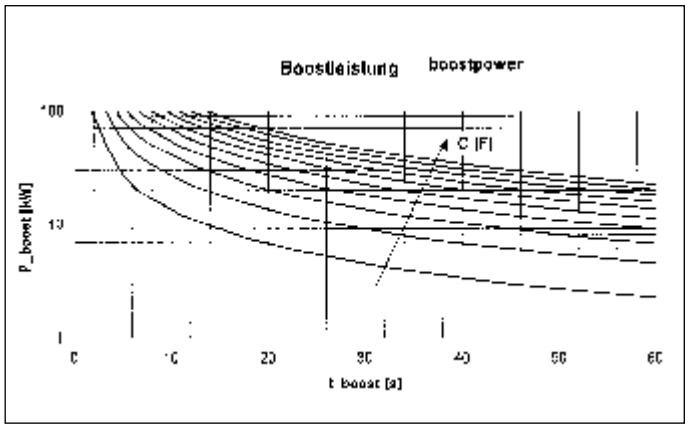

Fig 2: Required capacitance in depending on perfomance and duration of boost

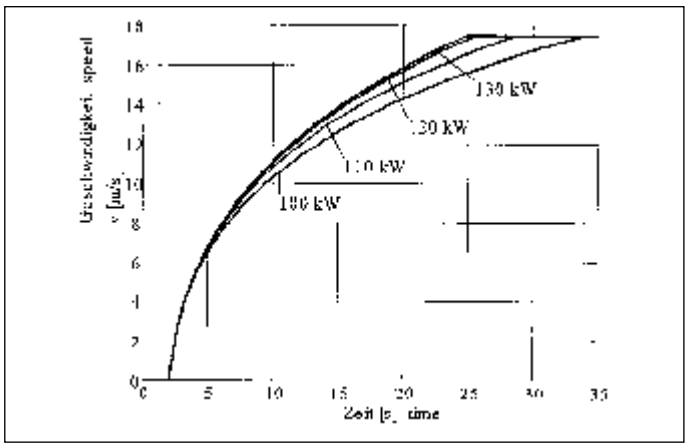

Fig. 3: Course of speed with different boostpower

termediate circuit from the condenser block, and the boost period (t_{boost}) with a condenser voltage of 600V. With a storage block of 6 F by 600 V around 27 kW can enter the intermediate circuit over 30 s.

Available space is the limiting factor to boost period and/or boost power. It is assumed that there is enough space on the vehicle for four ultracaps. Pure condenser weight would be 140 kg, the volume 92 l.

During boosting, electrical energy is taken from the supplementary storage. Maximum boost performance represents the difference between installed drive power and maximum generator power. *Figure 3* shows the acceleration curve with the appropriate total power. Here the time up to maximum speed reduces digressively and not linearly.

Diesel support during acceleration

With the installed supplementary storage it would also be possible to take over diesel engine power delivery during the period required for increasing rpm from idling to rated rpm. Hereby the total energy to be produced for the electric drive is taken from the supplementary electricity storage.

Starting procedure

In principle the generator can also be used as the starter for the diesel motor as long as energy is available from the intermediate circuit. This is also the case after the diesel engine has been switched off, as long as the condenser has been charged beforehand. Because condensers experience a certain amount of discharge through current leakage, or where the condensers have to be completely discharged for instance for safety reasons during servicing, a subsequent start is not always possible. In such cases the condenser must be charged from the battery over a further DC-DC converter or else the conventional starter used for starting the diesel motor. Possible, although unusual, is also a voltage monitoring of the storage block whereby the diesel engine starts when a minimum-charging rate is not reached so that the storage can be recharged by the generator. The conventional starter would not be required if a possibility was found of charging the condenser block before the diesel engine was started. Power and rpm are improved substantially when starting with ultracaps. For example, 50 % higher rpm at starting can be achieved by using ultracaps instead of the battery. This can also greatly reduce pollutant emissions from diesel starting. A second DC-DC converter should be used for charging the condenser block before diesel engine start. This can be the component of the DC-DC converter activated between condenser block and intermediate circuit. Thus component groups can be used for both applications. For example the control electronics can be used for both applications because at no time is the condenser block loaded from the battery at the same time as energy is fed into the intermediate circuit from the condenser block. *Figure 4* shows a possible switch. Basically three different concepts are possible for connecting the condensers: for every two current converters, elementary cells of „tiefsetzsteller“, „buck booster steller“ and „cuk steller“ can be unified to topologies allowing a power flow in both directions.

Literature

[1] *Dietrich,T.*: Elektrische Doppelschicht-Kondensatoren (Power Caps / Energy Caps) – Technologie und Anwendungsgebiete. VDI-Berichte Nr. 1418, Oktober 1998, S. 193-206

[2] *Angloher, J. und M. Schmid*: Die Kombination von Zink/Luft-Batterien und Doppelschichtkondensatoren für elektrische Fahrzeugantriebe. VDI-Berichte Nr. 1418, Oktober 1998, S. 207-221

[3] *Grusz, C. und M. Frey*: Vielleicht doch ein Kondensator. Design & Elektronik, 1998, S. 34-35

[4] • *Barucki, T.*: Optimierung des Kraftstoffverbrauches und der Dynamik eines dieselelektrischen Fahrantriebes für Traktoren. Dissertation, TU Dresden, 2001

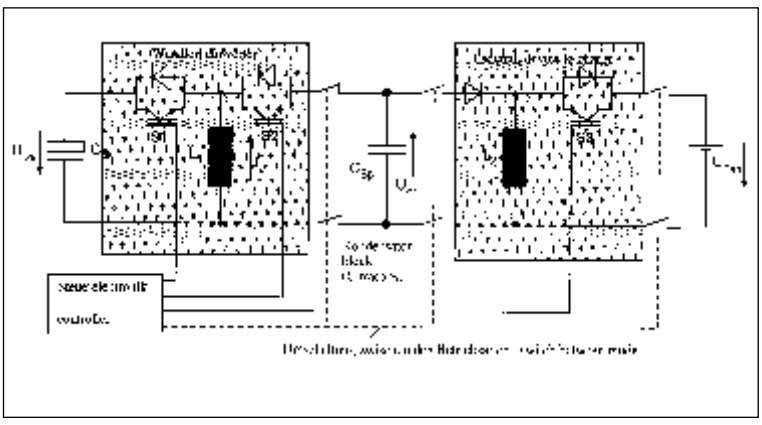

Fig. 4: DC-DC-converter with device to charge the ultracap from battery