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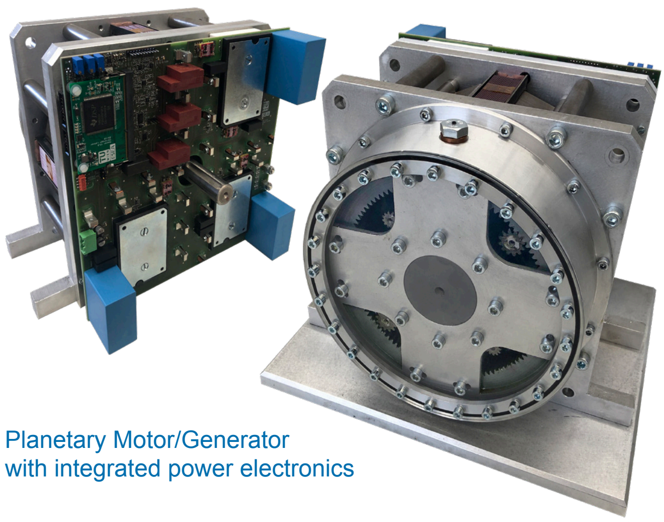
Multirotor e-drive for best performance

Highly efficient and lightweight Planetary Motor/Generator reduces costs

Electric motors for industrial and automotive drives usually gain their high power density by means of a high rotational speed. In order to reduce this rotational speed, and – depending on the purpose of use – to increase the torque, motors are equipped with gear units. The classic solution is to use the output shaft of the electric machine as input to a spur gear or a planetary gear. Thereby, the required rotational speed and torque are achieved. In doing so, motor and gear unit form two functionally and spatially separate components, which together form the most important part of the power train.

The rotor's rotational speed is limited by the strength properties of the rotor's material. Typically, peripheral velocities of 100-200 m/s can be achieved economically.

For many applications – from automotive to aerospace to robotics – an increased speed or reduced size and weight while reducing production costs of the e-drive would be of great advantage.



Planetary Motor/Generator
with integrated power electronics

Objective

Prof. Manfred Schrödl and his project group at the TU Wien aimed to develop a simplified yet particularly powerful motor-gear system. The focus was on finding a way to raise the performance limits of high speed engines, for example such as those required for e-mobility, by increasing the rotor speed, without raising the peripheral velocity.

In addition to combining the two separate functional units, transmission and electric machine, the power electronics should also be integrated into the electric machine as far as possible.

Solution

The basic idea for the newly developed drive system is to divide the single rotor of a conventional machine into several rotors. Their mechanical power is recombined via a gear. The toothed rotor shafts now already form part of the gearing. By clever design, several machines can be combined in a single stator, which generates several synchronous rotating fields with a common three-phase winding system. Thereby, copper and iron can be economised.

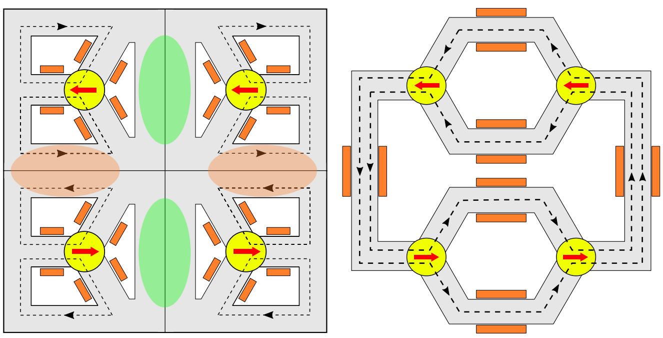
The magnetization in the synchronous revolving rotors (pairwise in opposite directions) is realised preferably by means of permanent magnets. It is, however, also possible to design reluctance rotors that function completely without any rare earth metals.

When divided into four rotors (as shown here), two rotors revolving into the same direction power a larger, inner-toothed gear (ring gear), while the two counter-revolving rotors power a smaller, externally-toothed gear (sun gear). Ring gear and sun gear rotate in the same direction and – given the appropriate dimensioning – with same angular velocity. Hence, ring and sun gear can be permanently integrated. When used as a generator, accordingly, all rotors are equally driven.

The arrangement of the four small gear wheels of the rotors within ring gear and sun gear resemble a 'planetary gear', name giver for this motor.

In another version of this machine concept, the replacement of the internally toothed ring gear by two externally toothed spur wheels is possible by changing the rotors' rotation directions. This makes it easier to manufacture the gear system. The stator geometry has also been modified in order to provide straight flux paths. This allows grain-oriented electrical steel to be used and thus further reduces iron losses.

In order to obtain an even more cost-effective system, the Planetary Motor can be controlled until standstill without sensors. This can be realised by means of the INFORM® method, used successfully for years in tens of thousands of electric drives. This method enables the elimination of error- prone sensors and leads to a further reduction of volume as well as assembly or maintenance mistakes. Thereby, a highly dynamic, robust and cost-effective drive is being achieved.



Basic principle: several similar machines combined in one common stator. This permits to eliminate inactive (green) and compensating areas (brown). The number of coils required is reduced considerably.

The new stator geometry allows the stator windings to be prefabricated and simply slipped onto the stator.

The Planetary Motor shown also demonstrates the complete integration of the power electronics on the front side of the motor. All coil connectors are mounted to one side of a high-current circuit board, which also contains the power electronics. This not only offers advantages for automated production, but also eliminates the otherwise necessary motor connection cables and all resulting EMC problems.

The electrical behaviour at the terminals of the Planetary Motor corresponds to that of a classic three-phase machine. Hence it is run by a conventional three-phase converter.

Applications

- e-mobility
- aerospace
- construction machinery or heavy equipment
- lifting equipment
- machine tools and production machines
- emergency units of various sorts
- drum drives
- robot joint drives

Your benefits

- very compact powertrain based on integration of motor and gear unit
- higher power density: up to +50% at same volume
- with four rotors: double performance compared to conventional machines with the same rotational cross-sectional area
- failure safety due to elimination of sensors
- enhanced efficiency at lower production cost
- significantly higher load capacity at given form and material quality of gearing
- extremely flat design possible
- especially suitable for safety-critical or high-performance application
- manufacturing with a high degree of automatization possible

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