GKN's ActiveConnect all-wheel drive system as an energy-efficient solution for electrified vehicles

Christoph Schmahl | 9/10.05.2019
AWD Systems in the Age of Electrification

- Electrified AWD vehicles are becoming increasingly popular
- Significant growth expected in the HEV/BEV market with East/West configuration

AWD is realized by an electrified secondary axis, which leads to dual motor systems with front hybridized HEV and with BEV.

Example: BEV with dual motor AWD

GKN Internal Analysis, 2018
Dual motor systems:
- Two separate drive units lead to high costs, low efficiency and mobility disadvantages

AWD systems in conventional vehicles:
- Mechanical drivetrain architecture allows use of a single source of propulsion power

GKN’s ActiveConnect AWD system allows to combine the best of both worlds to achieve
- high vehicle efficiency
- cost reduction
- enhanced mobility and driving dynamics
- low engineering and integration effort
ActiveConnect: How much AWD is needed?

**Road data acquisition**

- Test vehicles
- Road profiles

**AWD demand**

- Snow low-µ: 25%
- Country high-µ: 9%
- City high-µ: 14%
- Autobahn high-µ: 75%

**Demand**

- Snow: 75%
- Country: 91%
- City: 86%
- Autobahn: 100%

Most of the time AWD is not required!
GKN ActiveConnect-AWD Technology

Increased efficiency with ActiveConnect

PTU → Twinster RDU → Booster (Single Clutch RDU) → Modular Design

Dog Clutch: rotating parts, green parts on down time

Increased efficiency with ActiveConnect technology improves driving performance.

Throttle on – torque bias to outer wheel to mitigate under-steer

Throttle off – increased locking torque (both wheels) to mitigate over-steer
GKN ActiveConnect-AWD Technology

**Increased efficiency with ActiveConnect**

- PTU
- Twinster RDU
- Booster (Single Clutch RDU)
- Disc Clutches
- Modular Design
- Dog Clutch: rotating parts, parts on down time

**Twinster technology improves driving performance**

- Throttle on – torque bias to outer wheel to mitigate under-steer
- Throttle off – increased locking torque (both wheels) to mitigate over-steer

**Graphs:**
- Drag Loss [Nm] vs. Wheel Speed [rpm]
- Active AWD vs. Disconnected AWD
Simulation of three different BEV AWD concepts regarding the energy consumption:

- **Dual motor AWD (permanent)**
  - No disconnect
  - Permanent AWD
  - Motor: 50 kW front / 50 kW rear

- **Dual motor AWD (EDD)**
  - Front axle with disconnect
  - Efficiency optimized disconnect
  - Motor: 50 kW front / 50 kW rear

- **Single motor with mechanical ActiveConnect AWD**
  - Mech. AWD with ActiveConnect
  - Speed dependent disconnect
  - Motor: 100 kW front

**Vehicle parameter:**
- Mass: 1885 kg
- Front area: 2.6 m²
- Drag coefficient: 0.33

[Diagram showing the schematic illustration of clutch]
The ratio of power to efficiency of electrical machines is determined by the so-called growth laws [1].

Scaling up an electric machine by the factor $k$ in all its linear dimensions results in an increase [1]:

- of power by the factor $k^4$
- of volume by the factor $k^3$
- of energy losses by the factor $k^3$

With increasing motor power the efficiency and the ratio of power to costs improves [1].

**Conclusion:**
Replacing two low powered electrical machines with one high powered electrical machine results in improved efficiency and cost savings.

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Efficiencies of totally enclosed 4-pole induction motors [2]
Powertrain Efficiency (Example)

**Dual motor AWD**
- Low motor efficiency
- Double load independent losses of gearbox and inverter

**PMSM + Inverter** ($P_{\text{max}}=50$ kW)

**Gearbox**

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**Single motor with ActiveConnect AWD**
- High motor efficiency
- Load independent losses of single gearbox and inverter
- Low drag loss of PTU and RDU in disconnect

**PMSM + Inverter** ($P_{\text{max}}=100$ kW)

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**RDU - Disconnect**

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**PTU - Disconnect**

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Dual motor AWD Diagram
- Gearbox
- PMSM + Inverter ($P_{\text{max}}=50$ kW)

Single motor with ActiveConnect AWD Diagram
- RDU - Disconnect
- PTU - Disconnect
- Gearbox
- PMSM + Inverter ($P_{\text{max}}=100$ kW)
Efficiency Simulation Results

- Basis drive cycle: WLTP
- Simulation with a range of different PMSM
- Disconnection thresholds have been established below 40 km/h
- Potential energy savings by ActiveConnect AWD:
  - ~ 9 % vs. permanent dual motor system
  - ~ 6 % vs. dual motor system with EDD

(Battery: 60 kWh)

![Graph showing energy consumption for different drive configurations and speeds.](attachment:image_url)
Cost benefit is achieved by single motor concept due to:
- reduced number of complex drive components
- generating drive power by one central motor

Cost estimate based on current market prices:
- Inverters, motors, transmissions and ActiveConnect-AWD evaluated
- Cost of wiring, cooling and potential battery modification not considered
Mobility and Dynamics

- **Dual motor system**
  - Axle torque is limited to the torque of the respective motor

- **Single motor with mech. AWD**
  - Full torque available on both axles
  - Twinster enables torque vectoring and cross-axle locking
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  - Twinster enables torque vectoring and cross-axle locking
  - Mobility benefits on poor road surfaces and off-road, significantly improved driving dynamics
Application Scenarios for Electrified Vehicles

ICE

HEV (P1 – P3)

DHT

BEV

DHT with integrated PTU

eAxle with integrated PTU

GKN’s ActiveConnect system is the AWD solution for all vehicle concepts!
Application Scenarios for Electrified Vehicles

Ideal solution in the low and medium-price segment or in the commercial vehicle sector

➤ Cost reduction is particularly relevant
➤ Batteries tend to be smaller (simplified integration of propshaft)
➤ Effects of propshaft on passenger compartment are less critical
➤ Optimum use of the efficiency advantage
➤ Mobility benefit is especially considerable

Multi-speed transmissions are a challenge for dual motor systems

➤ two multi-speed gearboxes are needed
➤ or a compromise regarding efficiency and driving performance has to be found

AWD can be provided by mech. System with a single multi-speed transmission

Front: Booster
Rear: eTwinster 2speed with integrated PTU

Application Scenarios for Electrified Vehicles

**OEM with low market share in AWD**

- Hybridization of front axle to achieve high reduction in fleet consumption (P1 – P3/DHT)

**AWD options**

- **Electrified Rear Axle**
  - + Simplified battery design
  - + No impact on passenger compartment
  - - Additional engineering effort for rear axis

- **Mech. ActiveConnect AWD**
  - + Efficiency benefit
  - + Cost reduction
  - + Enhanced mobility and driving dynamics

**OEM with average market share in AWD**

- Option between P4 axle or P1 – P3/DHT with mechanical ActiveConnect-AWD

**AWD options**

- **P4 Axle**
  - + Simplified battery design
  - + No impact on passenger compartment
  - - Additional engineering effort for rear axis
  - + Hybridization covers full vehicle fleet
  - + Enhanced mobility and driving dynamics
  - + Electric AWD driving
  - + Recuperation on both axles
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AWD options

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Mech. ActiveConnect AWD

- Hybridization covers full vehicle fleet
- Enhanced mobility and driving dynamics
- Electric AWD driving
- Recuperation on both axles
As an alternative approach to dual motor solutions, AWD can be provided by GKN’s ActiveConnect system.

**Application scenarios for electrified vehicles**

- **BEV:**
  - Recommended for low and medium price segment or commercial vehicles
  - Beneficial for BEVs with multi-speed transmission

- **HEV:**
  - Recommended for OEMs with low to medium AWD market share

**Enhanced DRIVING DYNAMICS** due to Twinster Technology

**COST REDUCTION** by mechanical solution up to 13 %

**ENERGY SAVINGS** over 9 % possible, supported by growth laws and ActiveConnect

Full torque available on both axles for superior MOBILITY AND OFFROAD CAPABILITIES

GKN’s mechanical ActiveConnect system is the attractive AWD solution for hybrid and battery electric vehicles!
Global Leader in Traditional and Electrified Drivelines