Economical, ecological and efficient:

The intelligent response to increasing demands, the ELFA® Hybrid Drive
New perspectives for public transport companies: ELFA® the leading-edge hybrid drive

Based on more than 100 years of experience in electric drives and the concentrated force of innovation in our company, we realize solutions for all heavy duty applications in harsh environment.

In the competence center of Siemens Large Drives, our experts develop and manufacture side by side drive systems for industrial, marine, mining, train and road applications.

These synergies incorporate directly into the ELFA Hybrid Drive System.
# Siemens Electric Traction

<table>
<thead>
<tr>
<th>Rail</th>
<th>Road</th>
<th>Off - Road</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Rail Image" /></td>
<td><img src="image2" alt="Road Image" /></td>
<td><img src="image3" alt="Off-Road Image" /></td>
</tr>
</tbody>
</table>

Others:
- ![Others Image](image4)
- ![Others Image](image5)
- ![Others Image](image6)
Siemens Hybrid Drives - Product Portfolio
Focused competence from the global market leader: ELFA® from Siemens

With regional divisions in almost every country and 18 own facilities throughout the world we are always close to our customers.

More than 30 hybrid bus projects in Europe, North- and South America as well as in Asia demonstrate our global presence.

Hybrid Applications for city buses, delivery, port & garbage trucks, cranes, boats and construction machines demonstrate the flexibility and modularity of our ELFA Hybrid Drive System.
Increased degree of cost effectiveness and flexibility: The Serial Hybrid

The majority of the OEMs and suppliers concentrate on serial hybrid solutions for city buses. This decision is based on following key advantages of the serial hybrid system:

- **Standardization**, i.e. the same drive system can be used in diesel- and fuel cell hybrids
  
  This system has no direct, mechanical connection to the diesel engine, which offers:

- **Increased degree of freedom in the design**

- **Less noise due to gear-less drive**

- **Flexibility**, i.e. the serial hybrid drive is independent from the optimized diesel engine. The energy storage will improve in the years to come by the change to the Li-Ion technology, which requests a „downsizing“ of the diesel engine for achieving optimal results. The parallel system does not support this development schedule in an acceptable way, since they have a close relationship between the output torque of the diesel engine and the drive shaft torque.

- **Profitability**, the serial hybrid is the most cost effective solution for city buses that is based on the high fuel reduction results
## ELFA® Hybrid Drives for City Bus Applications

### Products

**Motor / Generator**
- Drive Motors and Generators from 30 kW to 180 kW

**Inverter / Control**
- Inverters and interface components with flexible usability of inverter phases, i.e. controls for
  - ASM motors
  - PEM motors
  - Braking resistances
  - DC-DC operations
  - 3phase and single phase hotel power
  - DC decoupling of energy storages

**Mechanical Integration**
- Axle and gearbox solutions for the mechanical integration

**System Configurations & Functions**
- 30 ft drive systems
- 40 ft drive systems
- 60 ft drive systems
- Braking resistors
- Various different battery types and ultra-capacitors
- Coupling to DC power sources, i.e. energy storages and fuel cells with up to two individual DC-DC converters
- DC decoupling of energy storages with IGBT's

**Functions**
- Drive Control Unit
- Energy Management
- Engine Control
- BMU Interface
- LOS-Modes
- Safety Controller
- System Diagnostic by SAE-CAN bus
There are two major types of electric hybrid systems available for city buses:

**Parallel Hybrid**
- Drive shaft
- Gear Box
- Electric Traction Motor/Generator
- Energy Storage
- Combustion Engine

**Serial Hybrid**
- Drive shaft
- Electric Traction Motor
- Fuel Cell
- Battery
- down-sized combustion engine
ELFA Hybrid Drive Modules provide Flexibility

ELFA = Flexibility!
ELFA Hybrid Drive Modules provide Flexibility

Siemens ELFA eDRIVE System

- **Power Generation Module**: Combustion Engine or Fuel cell
- **Traction Module**: Drive shaft and axle
- **Intermediate Circuit**: Nominal 650 V DC
- **Energy Storage Module**: (without energy storage)
- **Brake Resistor Module**
- **Auxiliary Power Module**
- **Battery or Ultra-capacitor**
- **1 Inverter Phase**
- **Free choice of bus OEM**

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Industry Sector DT LD CoC
ELFA Hybrid Drive Modules provide Flexibility

Flexibility in Integration

ASM (asynchronous motor) and gearbox drive solution for 12m buses with standard performance. Today the most cost efficient solution for volume production available.

Electric low-floor axles with ELFA induction ASM-Motors offer wide aisles at very low floor heights.

Innovative PEM (permanent magnet) motor technology for high powered buses from 12m up to double-articulated buses with high performance requirements.
ELFA Hybrid Drive Modules provide **Flexibility**

### Power Generation Module

<table>
<thead>
<tr>
<th>Power Generation Module (PGM)</th>
<th>Combustion Engine Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 1FV5135 + Damping Coupling</td>
<td>1 Mono Inverter 90</td>
</tr>
<tr>
<td>P2 1FV5139 + Damping Coupling</td>
<td>1 Mono Inverter 125</td>
</tr>
<tr>
<td>P3 1FV5139 + Damping Coupling + Step-up Gear</td>
<td>1 Mono Inverter 160</td>
</tr>
<tr>
<td>P4 1FV5168 + Damping Coupling</td>
<td>1 Mono Inverter 160</td>
</tr>
<tr>
<td>P5 1FV5168 + Damping Coupling + Step-up Gear</td>
<td>1 Mono Inverter 240</td>
</tr>
<tr>
<td>P6 1DB2007 + Damping Coupling</td>
<td>1 Mono Inverter 200</td>
</tr>
<tr>
<td>P7 2 Inductance Boxes</td>
<td>1 Mono Inverter 120 kW*)</td>
</tr>
</tbody>
</table>

*) = Fuel Cell

**Flexibility in Bus Size**
ELFA Hybrid Drive Modules provide **Flexibility**

### Flexibility in Bus Size

<table>
<thead>
<tr>
<th>Traction Module incl. DICO (TMD)</th>
<th>Bus Type (length in m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1</strong> 2 x 1PV5135 + Summation Gear</td>
<td>2 Mono Inverter</td>
</tr>
<tr>
<td><strong>T2</strong> 2 x 1PV5138 + Summation Gear</td>
<td>2 Mono Inverter</td>
</tr>
<tr>
<td><strong>T3</strong> 1DB2016 + VPM</td>
<td>1 Mono Inverter</td>
</tr>
<tr>
<td><strong>T4</strong> 1DB2016 + VPM (6 ph)</td>
<td>2 Mono Inverter</td>
</tr>
<tr>
<td><strong>T5</strong> 1DB2024 + VPM (6 ph)</td>
<td>2 Mono Inverter</td>
</tr>
<tr>
<td><strong>T6</strong> 2 x 1PV5135 + ARM axle</td>
<td>2 Mono Inverter</td>
</tr>
<tr>
<td><strong>T7</strong> ZF axle including 2 motors</td>
<td>2 Mono Inverter</td>
</tr>
</tbody>
</table>

* = flat topography
ELFA Hybrid Drive Modules provide **Flexibility**

**Flexibility in Energy Mix**

![Diagram showing energy mix and operating range](image)

- **Power**
  - 100%
  - 0%

- **Operating Range**
  - **ELFA**
  - **Generator Set** (diesel, gas, gasoline)
  - **Fuel Cell**

- **Energy Storage**

- **Tendency due to improved energy storage performance**

- **Energy Mix**
  - diesel-electric
  - battery hybrid ("down-sizing")
  - battery hybrid
  - pure battery
  - hybrid fuel cell
  - pure fuel cell

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Industry Sector DT LD CoC
ELFA® Hybrid Drive System for 12m City Bus with Ultra-capacitor
Required ELFA® Components for a 12m City Bus

- 2 ELFA drive motors on a summation gear
- 2 ELFA Mono inverters to operate the drive motors
- ELFA Gateway Unit – drive control, hybrid control, safety control and communication with the CAN-bus system of the vehicle
- 2 ELFA inductance boxes
- 1 ELFA generator with step up gear
- 1 ELFA MONO inverters to operate the generator
- Ultra-cap unit (not Siemens, i.e. ISE)
- ELFA Braking resistor

Additional: power and control cables, cooling system for the ELFA components (ca. 50 °C)

July -2009
World-wide Hybrid Bus Projects – TUTTO Fuel Cell Hybrid (BRA)

<table>
<thead>
<tr>
<th>Power Module</th>
<th>Traction Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>T1</td>
</tr>
<tr>
<td>P2</td>
<td>T2</td>
</tr>
<tr>
<td>P3</td>
<td>T3</td>
</tr>
<tr>
<td>P4</td>
<td>T4</td>
</tr>
<tr>
<td>P5</td>
<td>T5</td>
</tr>
<tr>
<td>P6</td>
<td>T6</td>
</tr>
<tr>
<td>P7</td>
<td>T7</td>
</tr>
</tbody>
</table>

- **2 x 1PV5138 + Summation Gear**
- **2 Mono Inverter**

- **Prototype vehicles**
  - **2 Inductance Boxes**
  - **1 Mono Inverter**
World-wide Hybrid Bus Projects – Wrightbus Fuel Cell Hybrid (UK)

London leading the way in hydrogen

10 vehicles sold *)

2 x 1PV5138 + Summation Gear
2 Mono Inverter

2 Inductance Boxes
1 Mono Inverter

*) = via ISE Corp.
World-wide Hybrid Bus Projects –
Mercedes Citaro Fuel Cell (GER)

Pre-series 2009, Fleet Test 2010

ZF axle including 2 motors
2 Mono Inverter
World-wide Hybrid Bus Projects – Van Hool Fuel Cell Hybrid (B)

- Van Hool Fuel Cell Hybrid (B)
- T7 P7
- T6 P6
- T5 P5
- T4 P4
- T3 P3
- T2 P2
- T1 P1

- Energy storage
- Power of combustion engine
- Fuel cell

- 2 x 1PV5138 + Summation Gear
- 2 Mono Inverter

- 2 Inductance Boxes
- 1 Mono Inverter

- Approx. 15 vehicles sold
World-wide Hybrid Bus Projects – New Flyer*) Fuel Cell Hybrid (USA)

- Power of combustion engine
- Fuel cell
- Energy storage

2 x 1PV5138 + Summation Gear
2 Mono Inverter

20 vehicles sold *)

2 Inductance Boxes
1 Mono Inverter

*) = via ISE Corp.
World-wide Hybrid Bus Projects – Wrightbus DD (UK)

Approx. 20 vehicles sold

Energy storage
Power of combustion engine
Fuel cell

Power module
Traction module

<table>
<thead>
<tr>
<th>P1</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>T2</td>
</tr>
<tr>
<td>P3</td>
<td>T3</td>
</tr>
<tr>
<td>P4</td>
<td>T4</td>
</tr>
<tr>
<td>P5</td>
<td>T5</td>
</tr>
<tr>
<td>P6</td>
<td>T6</td>
</tr>
<tr>
<td>P7</td>
<td>T7</td>
</tr>
</tbody>
</table>

FV5139 + Damping Coupling
1 Mono Inverter

2 x 1PV5138 + Summation Gear
2 Mono Inverter
### Drive Motor 1PV5138-4WS24-W12

<table>
<thead>
<tr>
<th>Type</th>
<th>AC Induction Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Media</td>
<td>Water-Glycol</td>
</tr>
<tr>
<td>Rated Voltage DC</td>
<td>650 V</td>
</tr>
<tr>
<td>Rated Power</td>
<td>85 KW</td>
</tr>
<tr>
<td>Rated Torque</td>
<td>220 Nm</td>
</tr>
<tr>
<td>Max. Torque</td>
<td>530 Nm @ 300A</td>
</tr>
<tr>
<td>Rated Current</td>
<td>142 A</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>10,000 rpm</td>
</tr>
<tr>
<td>Weight</td>
<td>120 kg</td>
</tr>
<tr>
<td>Dim. (LxWxH)</td>
<td>510 x 245 x 245 mm</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>-30 °C to 70 °C</td>
</tr>
<tr>
<td>Degree of Protection</td>
<td>IP 65 / 9k</td>
</tr>
</tbody>
</table>
**Auxiliary Motor**

**Auxiliary Drive Motor 1PV5131-4WS52**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>AC Induction Motor</td>
</tr>
<tr>
<td>Cooling Media</td>
<td>Water-Glycol (8 l/min)</td>
</tr>
<tr>
<td>Rated Voltage DC</td>
<td>450 - 650 V</td>
</tr>
<tr>
<td>Rated Power</td>
<td>20 KW / 3.000 rpm</td>
</tr>
<tr>
<td>Rated Torque</td>
<td>65 Nm (&lt; 3.000 rpm)</td>
</tr>
<tr>
<td>Max. Torque</td>
<td>120 Nm @ 90A</td>
</tr>
<tr>
<td>Rated Current</td>
<td>54 A</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>5,000 rpm</td>
</tr>
<tr>
<td>Weight</td>
<td>54 kg</td>
</tr>
<tr>
<td>Dim. (LxWxH)</td>
<td>320 x 245 x 245 mm</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>- 30 °C to 70 °C</td>
</tr>
<tr>
<td>Degree of Protection</td>
<td>IP 54</td>
</tr>
</tbody>
</table>
Example Cooling Circuit
Future in E-Traction > Gear-less Drive: i.e. PEM-Motor 1DB2024

<table>
<thead>
<tr>
<th>Type</th>
<th>PM Synch. Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Media</td>
<td>Water-Glycol</td>
</tr>
<tr>
<td>Rated Voltage DC</td>
<td>750 V</td>
</tr>
<tr>
<td>Rated Power</td>
<td>260 KW @ 1500 rpm</td>
</tr>
<tr>
<td>Rated Torque</td>
<td>2700 Nm @ 360 A</td>
</tr>
<tr>
<td>Max. Torque</td>
<td>4500 Nm @ 600A</td>
</tr>
<tr>
<td>Rated Current</td>
<td>360 A</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>3.500 rpm</td>
</tr>
<tr>
<td>Weight</td>
<td>500 kg</td>
</tr>
<tr>
<td>Dim. (L x W x H)</td>
<td>660 x 510 x 500 mm</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>- 30 °C to 70 °C</td>
</tr>
<tr>
<td>Degree of Protection</td>
<td>IP 65 / 9k</td>
</tr>
</tbody>
</table>

- Successful market introduction (Las Vegas Project)
- Performance targets verified
- Series development started (weight and cost optimization)
- Series production 2010
ELFA® Operating Experience (1)
Status April 2008

MAN diesel-electric
Gillig Hybrid
Mercedes diesel-electric
Iveco Hybrid

Hino Hybrid
Iveco diesel-electric
MAN Fuel Cell
BMB 12m Hybrid

Mitsubishi Hybrid
MAN Ultra Cap Hybrid
Battery School Bus
OCC Hybrid

ISE, Fuel Cell Hybrid Bus II
SBETI, 30ft Battery Bus
BMB 10m Hybrid Bus
ISE, 40ft Hybrid Bus
ELFA® Operating Experience (2)
Status April 2008

ISE, 40ft Gasoline Hybrid Bus
ISE, 40ft HICE Hybrid Bus
ISE, 40ft HICE Hybrid Bus
ISE, Hybrid Shuttle Bus
ISE, Hybrid Shuttle Bus
Azure Hybrid Shuttle Bus

CEV, 40ft Hybrid Bus
ISE, 40ft Fuel Cell Hybrid Bus
ISE, 40ft Fuel Cell Hybrid Bus
Tutto, 40ft Fuel Cell Hybrid Bus
Tutto, 40ft Fuel Cell Hybrid Bus

MAN, Fuel Cell Hybrid Bus
ISE, 40ft Diesel Hybrid Bus
ISE, 40ft Diesel Hybrid Bus
Wrightbus, Doubledeck Diesel Hybrid Bus
Wrightbus, Doubledeck Diesel Hybrid Bus

FCC, Hybrid Garbage Truck
ISE, 30ft Diesel Hybrid Bus
ISE / Wrightbus 60ft Diesel Hybrid Bus
ISE / Wrightbus 60ft Diesel Hybrid Bus
Van Hool 13m Fuel Cell Hybrid
Van Hool 13m Fuel Cell Hybrid

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Industry Sector DT LD CoC
Reasons to buy hybrid buses

- The hybrid bus needs to be obviously different from the standard diesel bus
  - pure electric operation into and from the bus stop (constant behavior at all conditions/inclines)
  - prevention of excessive diesel engine noise – peak power always from the energy storage
  - absolute jerk-free acceleration ("tram-feeling")
  - modern design – e.g. more low-floor area
- The hybrid bus must clearly save fuel and emissions, i.e. technically – highest possible braking energy recuperation; in a standard 12m bus this is approx. 150 kW
- the electric drive (components) must remain unchanged in future when new, more powerful energy storages and smaller diesel engines will dominate the hybrid drive system. (easy retrofit will be possible). Long-term the small diesel engine can be replaced by a small fuel cell
ELFA® - Advantages at a Glance

- Up to 40 percent less energy consumption and exhaust emission
- Emission-free operation possible in inner city areas and at bus stops
- Noticeably more quiet
- Higher degree of comfort for passengers as the bus accelerates a lot more smoothly
- Extremely reliable and low-maintenance traction systems
- All components from a single source – motor, generator, traction converter and control
- Serial hybrid system concept for maximum degree of flexibility and cost effectiveness
- Can be adapted to all city bus types as a result of the modular design
- Proven thousands of times over
WHY SIEMENS?

- Electric Traction is core competence of since more than 100 years

- The ELFA® Hybrid System made specifically for road application is already more than 12 years successfully in operation

- All major drive components are produced in-house

- Sales & Service is available around the globe

- Capable to create volume production through synergies in other business areas with ELFA system, i.e. off-road, special machinery and boats. ➔ volume will lead to scale effects with positive effect on pricing

- Capable of working with all vehicle OEMs as well as system integrators around the world

- Financially sound company – will stay with its customers in “good and in bad times”
Thank you!

Antonio Claudino

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