Hybrid Drive Systems for Vehicles

Auxilliary Systems and Safety

Hybrid Drive Systems for Vehicles

Auxilliary systems

Auxilliary systems ?

- Fundamental support functions
  - *Power Steering*
  - *Power Brakes*
  - *Air pressure (heavy vehicles)*
  - *Lighting*
  - *Ventilation*
  - *Suspension*
  - *12/24 V system*
- Comfort function
  - *Air Conditioning*
  - *Power windows, seats, ...*
  - *Entertainment systems*

Auxilliary systems cannot be disregarded

- Energy consumption and peak power significant
  - *Sometimes in parity with the tractive energy*

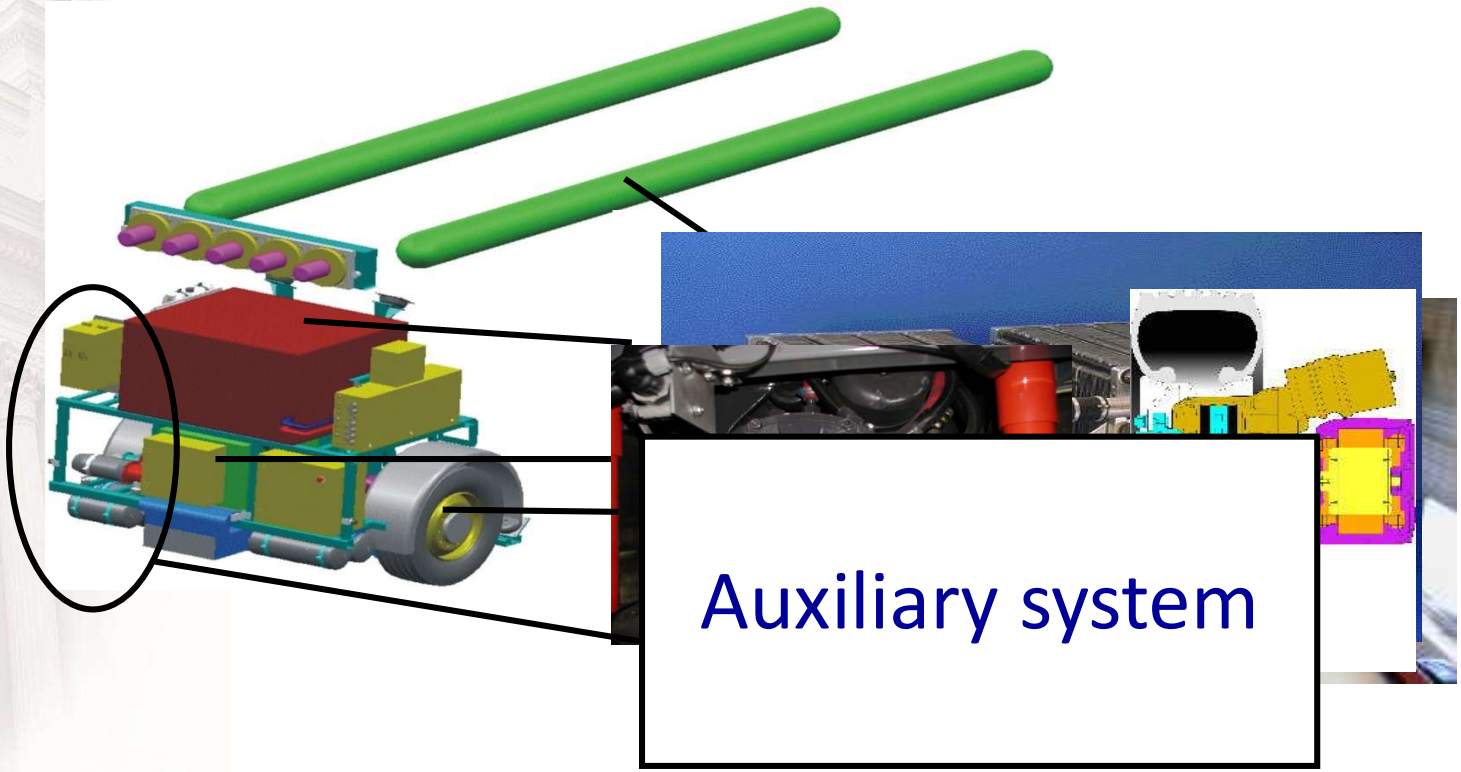
- Two distinct goals:
  1. *Minimize energy consumption*
  2. *Limit peak power*

Means ..

- Technology selection
  - *Mechanical to electric*
  - *Pneumatic to electric*
  - *Hydraulic open loop to closed loop*
  - *Hydraulic to electric*
  - *... to increase efficiency*
- Control and scheduling
  - *Load ”shaving”, e.g.:*
    - reduce compressor speed at high load, or
  - *Intelligent use of braking energy, e.g*.
    - regenerate energy to aux systems like compressor when the bus is braking.

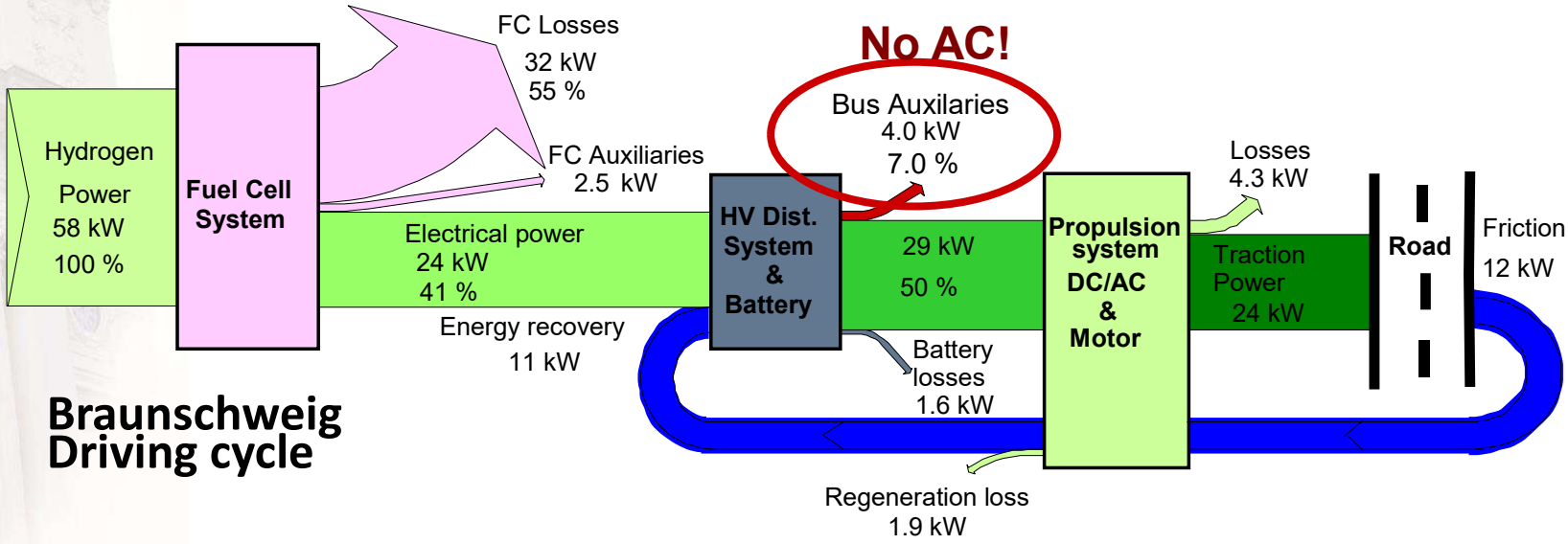
Te

Drive train

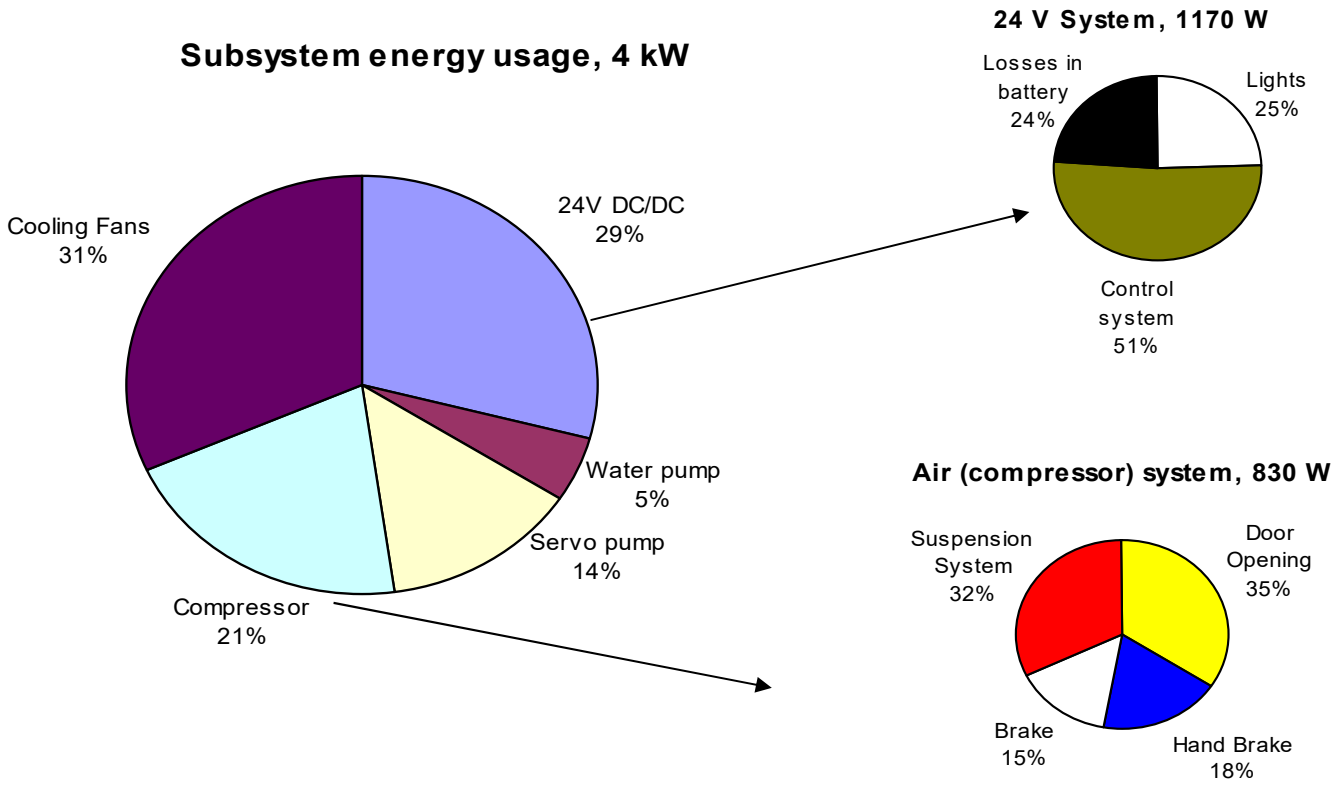


Energy balance in the bus

(in average powers)

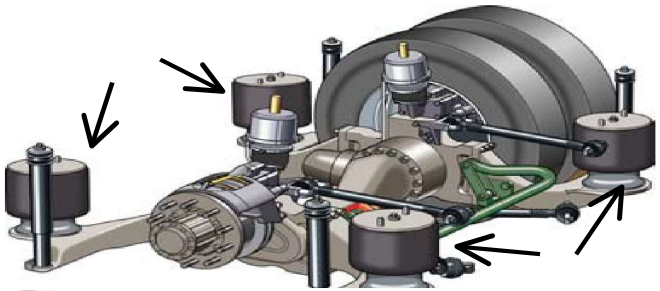


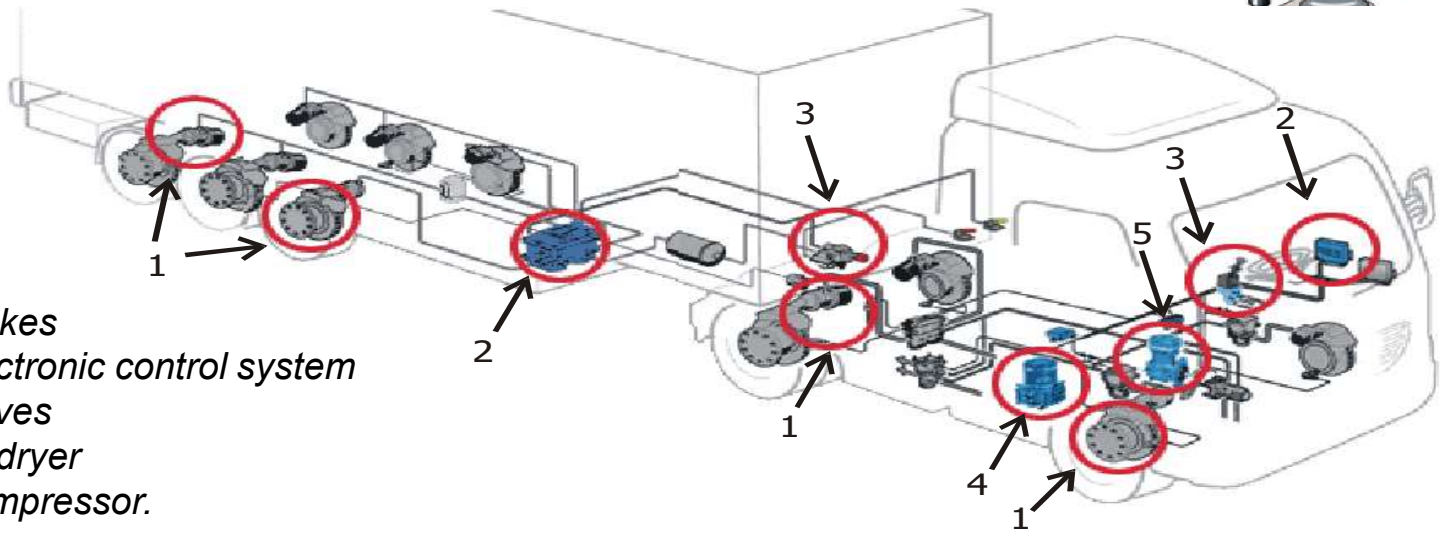
Auxiliary system – energy consumption



Air pressure driven loads

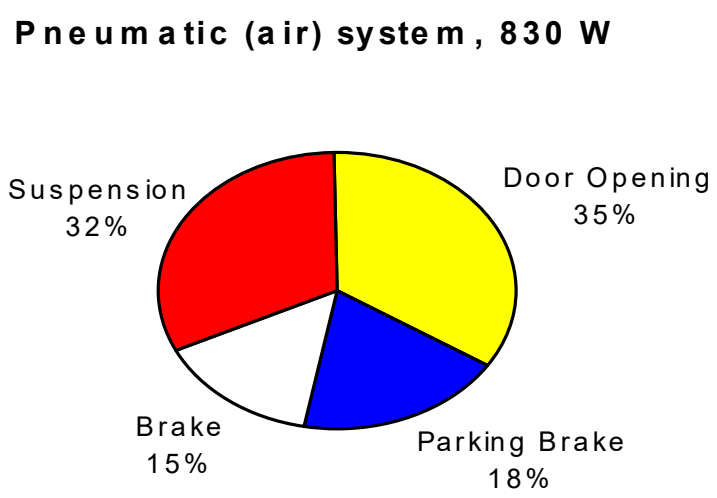
- Brakes
- Suspension
- Door opening





1 Brakes
2 Electronic control system
3 Valves
4 Air dryer
5 Compressor.

New technology selection

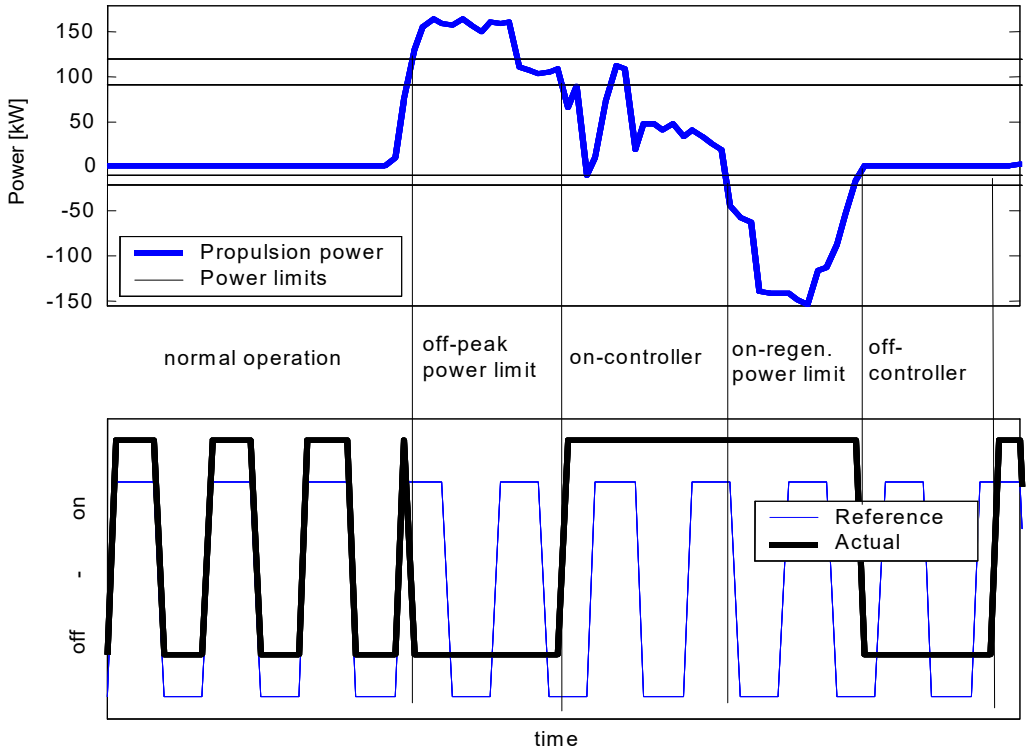


System	Pneum [W]	El [W]
Doors	230	20
Suspension	260	25
Parkering Brake	150	10

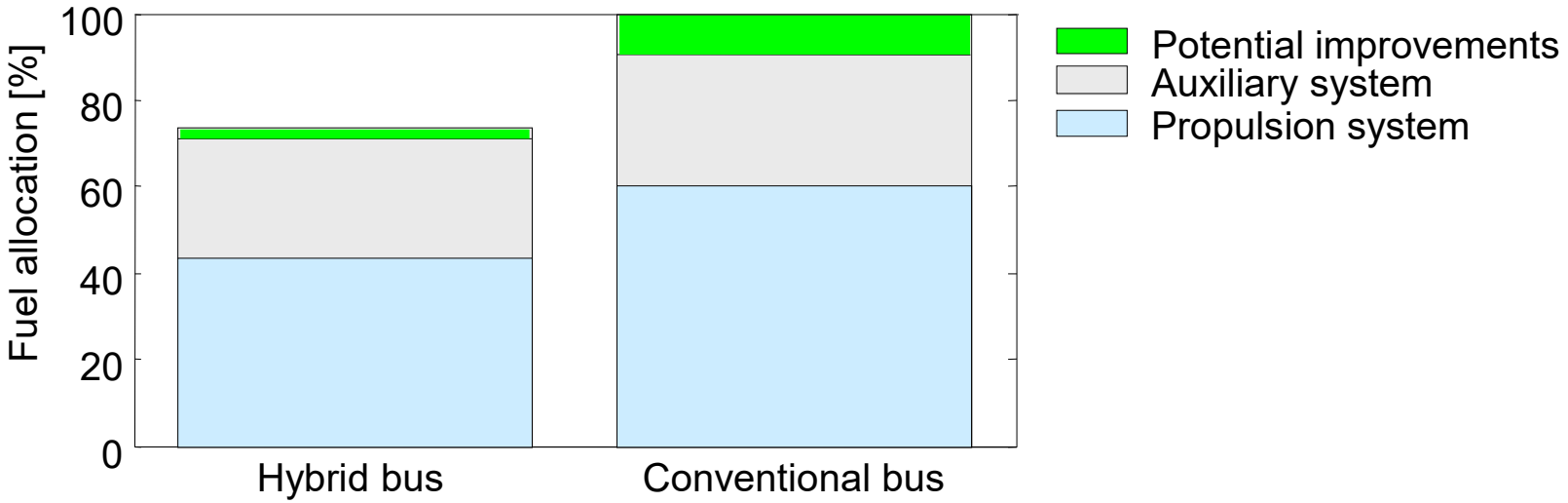
Control


Speed [km/h]
60
40
20
0
200
260
280
300
320
340
360
380
400
seconds
Peak Shaving
Power [kW]
120
100
80
60
40
20
0
-20
-40
-60
-80
Propulsion
AC+DC/DC+Propulsion
200
220
300
320
340
360
380
400
seconds
Run at full power

AC-system on/off condition duty cycle generator



Potential improvements of the auxiliary system



Conventional electric loads in a car

Engine Management	Power (W)
Fuel Pump& Injectors	135
Ignition System	60
Electronic Throttle Sys.	60
Sensors & Actuators	110
Solenoids & Relays	20
Subtotal Engine	**385**
Amps @14.2V	27.11

Multimedia & HVAC	Power (W)
High end audio sys.	300
Navigation and GPS	150
Driver information display	30
Cabin climate valves	75
Blower motor + ECU	370
Subtotal Cabin Sys.	**925**
Amps @14.2V	65.14

Body Electrical	Power (W)
Power Windows (4)	560
Power Door Locks (4)	200
Wipers and washers	140
Heated backlight	500
Power seats (2)	460
Subtotal Body Sys.	**1860**
Amps @14.2V	130.99

Chassis Electrification	Power (W)
Electric assist steering	300
ABS brake system	200
Air suspension valves	50
Air compressor	500
Subtotal Chassis	**1050**
Amps @14.2V	73.94

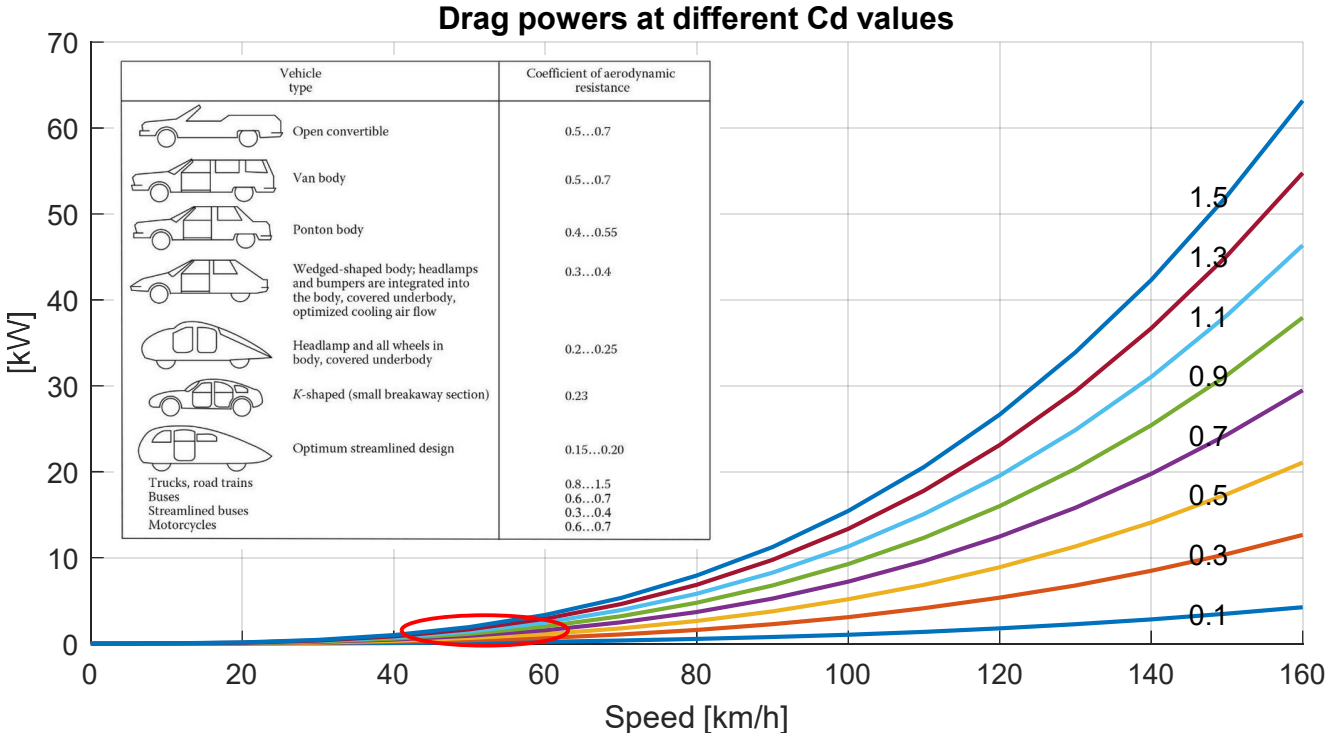
Lighting (Exterior & Interior)	Power (W)
Headlamps (2)	120
Running/Park lights (4)	130
Turn signal lamps	130
Center high mount stop	65
Back-up, interior, license	45
Subtotal lighting	**490**
Amps @14.2V	34.51

Future Systems	Power (W)
DVD and in-seat displays	
Micro/Mild-hybrid functions	
Active suspension	
Front/rear radar	
Obstacle detection & Airbags	
Active cruise control	
Total Electrical/Electronics	**4710**

Charging System	Power (W)
Alternator	3000
Battery (80 Ah)	1000
Starter motor	2200

Drag powers ...

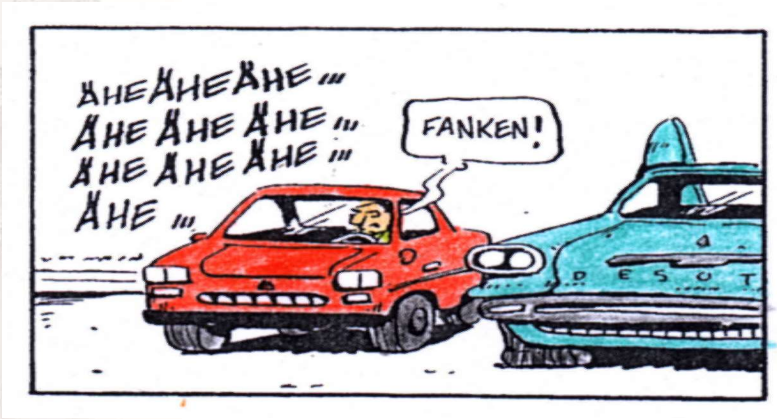
- Remember generator load 1… 2 kW !



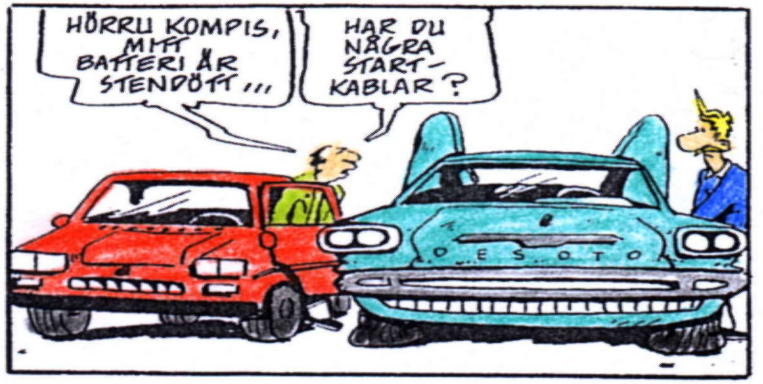
To much ...?

- The conventional generator is not able to provide enough power to supply all loads ...
- Higher power is needed!
- Is 12 Volt enough?

Ernie I



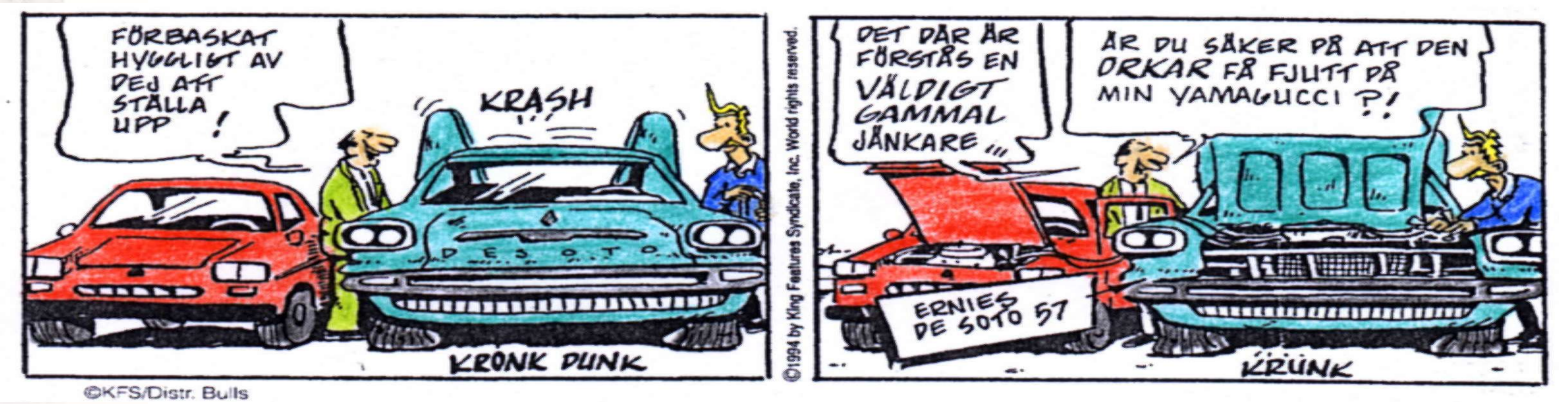
Damn!



- Hi mate, my battery is dead ...

- Do you have any jumper cables?

Ernie II

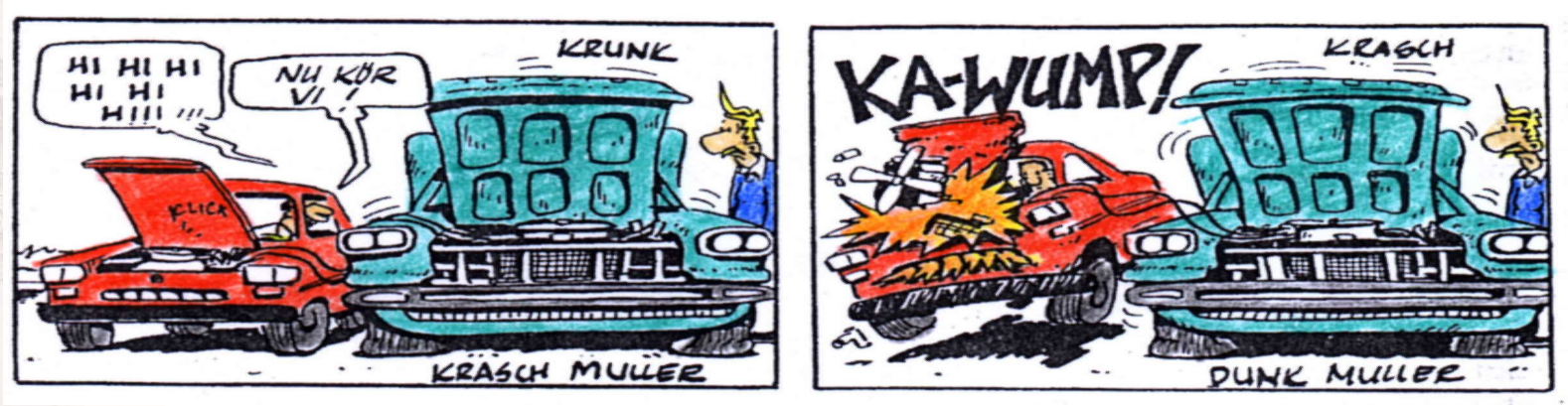


- Damn kind of you to help me out !

- That is of course a VERY OLD yankee ..

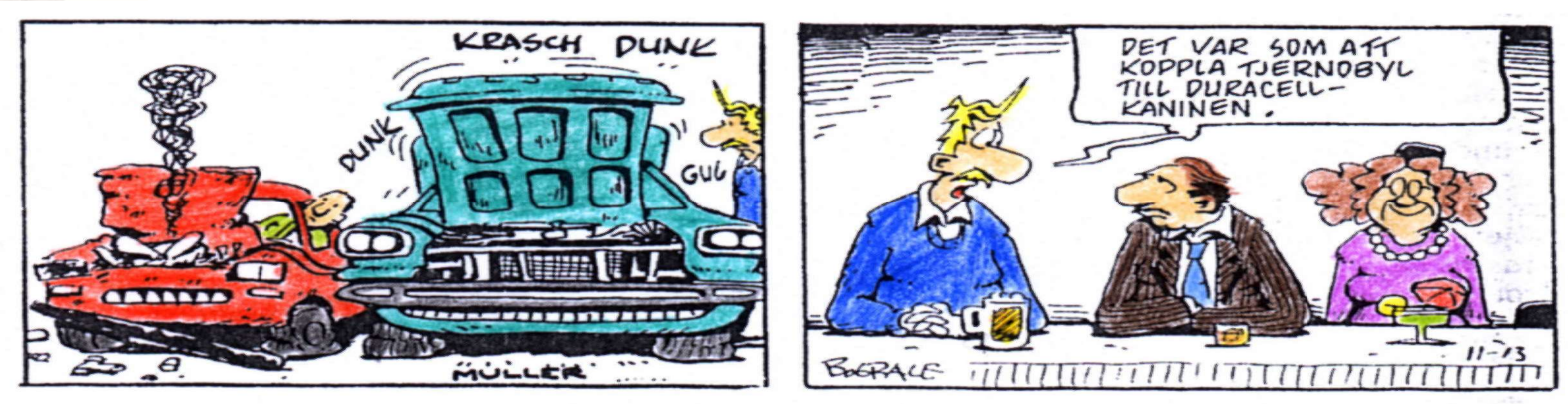
- Are you sure that it can make my Yamagucci spin?

Ernie III



- OK, lets go !

Ernie IV



- It was like connecting Tjernobyl to the Duracell Rabitt

The 12 V story

- 6 V to begin with
- 6 V electric generator and starter 1912
- 6 V not enough – higher load and compression
- 12 V introduced 1955
- Still used, up to 1 kW
  - No electric hazard
  - Modest isolation requirements
  - Easy fusing

- Maximum power ?

Problems with increased load @ 12 V

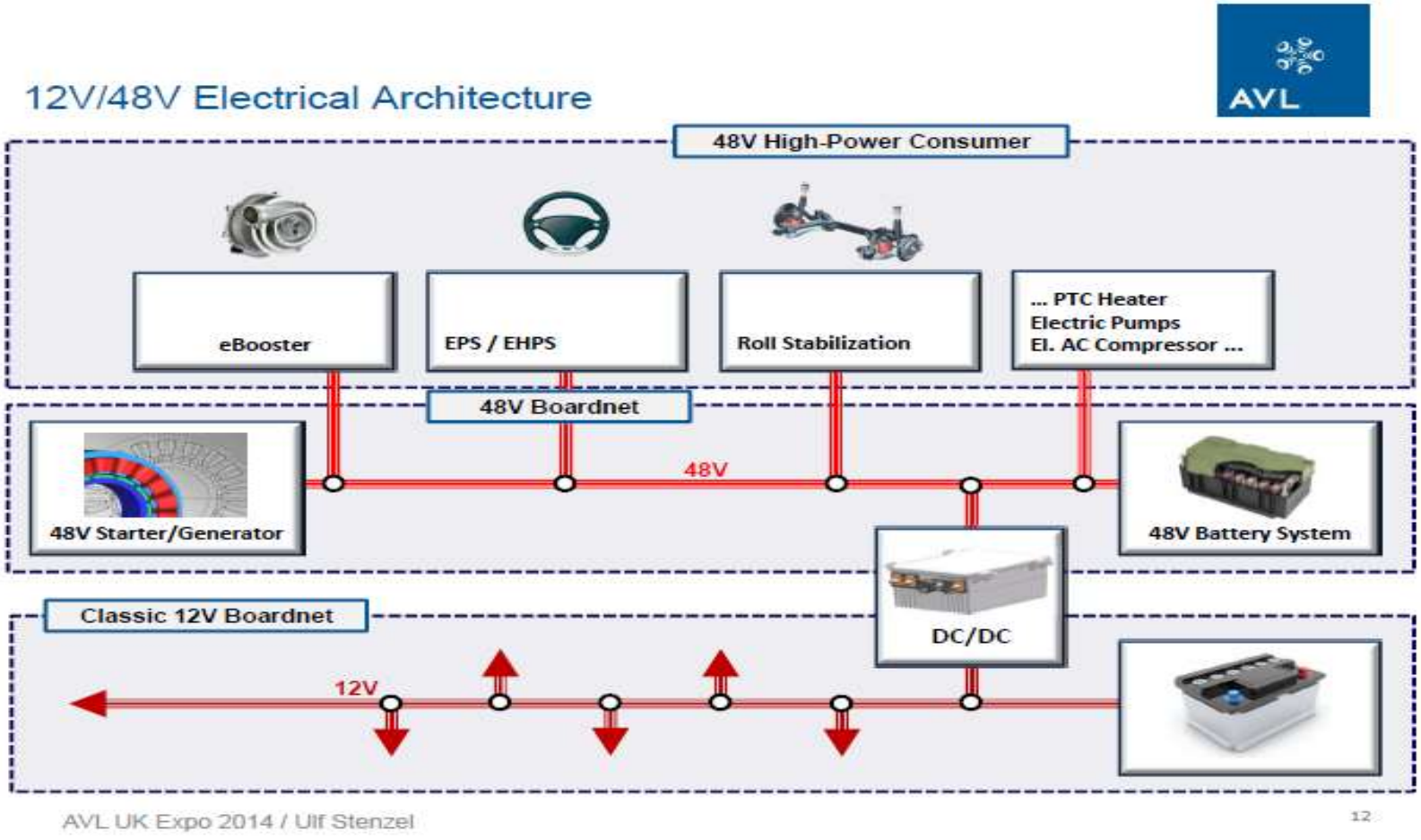
- Cable area becomes large
  - 1 kW needs 8 mm diameter cable
  - 4 kW need 16 mm diameter cable
  - 10’s of kW needs ...
- Connectors becomes expensive
  - Voltage drops must be kept very low

So, how much more do we need?

- 1992 MIT and Mercedes Benz took the initiative to a 42 V system voltage
- 42 ?, = 3*14 = charging voltage of a 36 V battery.

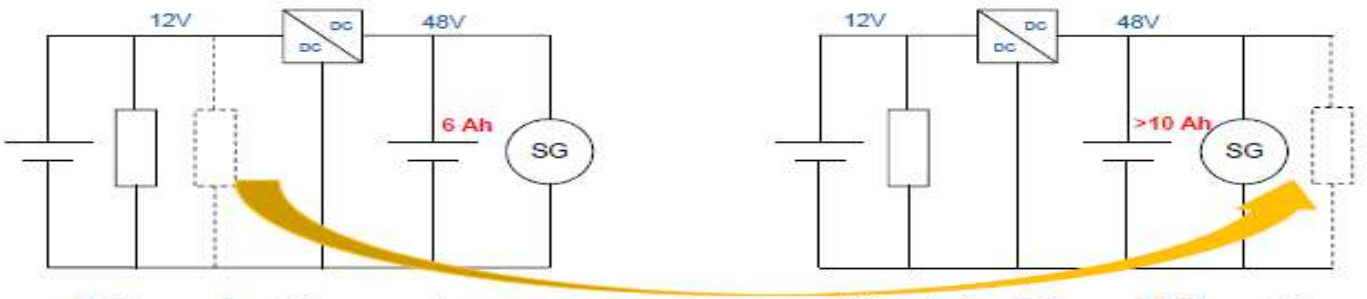
- Problems with 42 V:
  - Still not enough, in particular for hybrid power levels
  - Windings in machines bigger
  - Fusing more expensive
  - Filament lamps last shorter

48 V this time



CO2 and Load Migration

48V Electrical Load Migration – Impact on eStorage



CO_2 reduction only
Start/Stop, Boost, Recuperation

Electrical Load Migration
Chassis Control, Climate
Comfort, Engine Components
Electrification, eBooster, etc…

Different Voltages

System Comparison

Hybrid systems vs main functions

● : Possible
○ : Limited
GSI : Gear Shift Indicator

	i-StARS 14V (2 to 4 kW)	i-BSG 48V (8 to 12 kW)	GMG 48V (8-15kW)	CMG > 48V (15 to 90 kW)
Cold start	○	●	●	●
Change of Mind	●	●	●	●
Stop & Start	●	●	●	●
HE generator	●	●	●	●
Durability (1mcy)	●	●	●	●
Comfort Start	●	●	●	●
Stalling help	●	●	●	●
Sailing / coasting	●	●	●	●
Boost (GSI*)	○	●	●	●
Regenerative	○	●	●	●
Torque Monitoring	○	●	●	●
Electrical Take off		○	●	●
Electrical drive /ZEV			○	●

Valeo

FE Benefits from Stop-Start to 12v-48v Hybrids

Fuel economy gain & CO_2 reduction

Stop-Start 12V

Stop-Start at 0 mph speed

Stop-Start 12V

Stop-Start until 12 mph speed Change of Mind

Stop-Start Coasting 12V

Stop-Start until 60 mph speed Change of Mind & coasting Regen 5kW

Mild HEV Coasting 48V

Stop-Start Change of Mind & coasting Regen & Boost 12kW

Estimate fuel economy benefits

NEDC	**3% - 4%**	**4% - 6%**	**6% - 8%**	**10% - 15%**
WLTC	**2% - 3%**	**3% - 4%**	**12% - 15%**	**15% - 20%**
FTP	**3% - 4%**	**4% - 5%**	**10% - 13%**	**15% - 20%**

Valeo

High voltage?

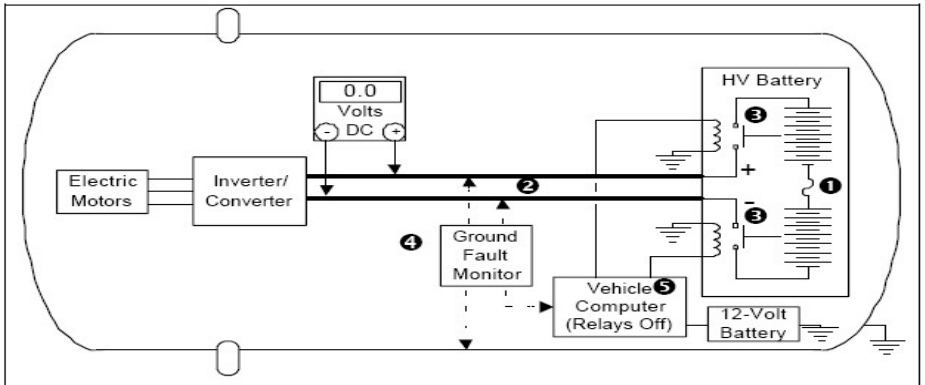
- > 1.5 V
- > 15 V
- > 50 V
- > 150 V
- > 300 V
- > 3 kV

- **> 50 V is regarded as high**
- **48 V common**
- **36/42 V …**

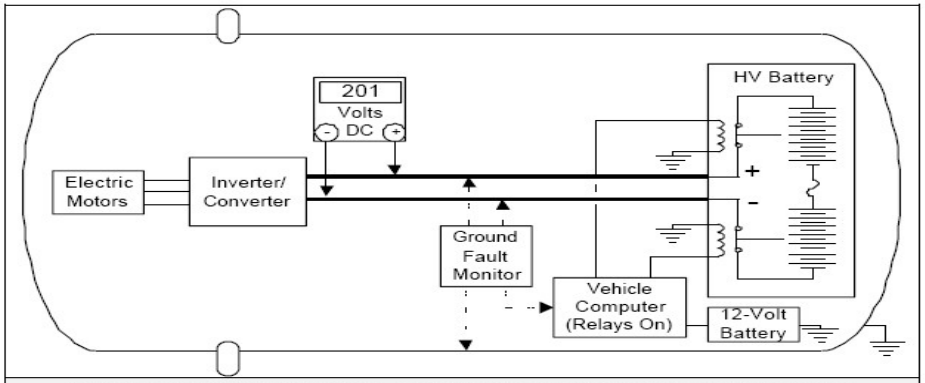
What is a dangerous equipment?

- Equipment where a fault can cause harm to a person or property.
- 12 V system can also be dangerous
  - Can cause fire
  - Hydrogen explosion possible
- Even if the voltage is low, the short circuit current is high and thus also the possible heat dissipation

Toyota Prius safety system



High Voltage Safety System – Vehicle Shut Off (**READY**-off)



High Voltage Safety System – Vehicle On and Operational (**READY**-on)

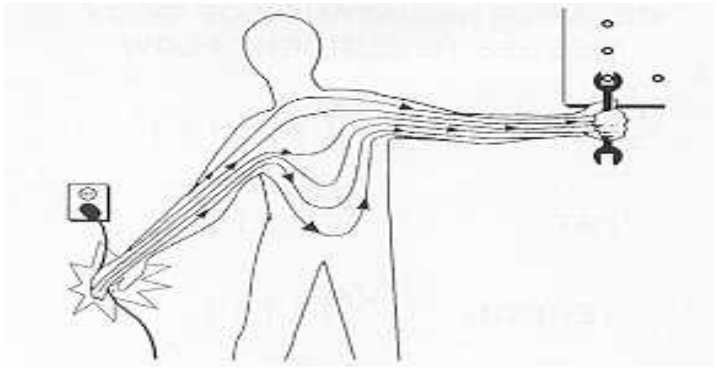
Basic dangers

1. Direct current through body
2. Short circuit current that cannot be interrupted
3. High output voltage from switching converters
   - Also EMC
4. Parasitic currents from switching converters

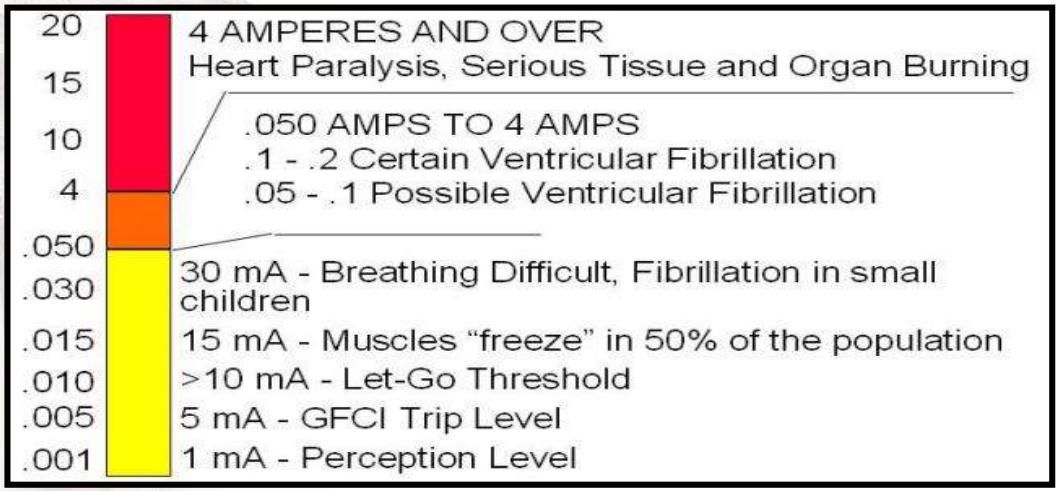
5. Fire or explosion

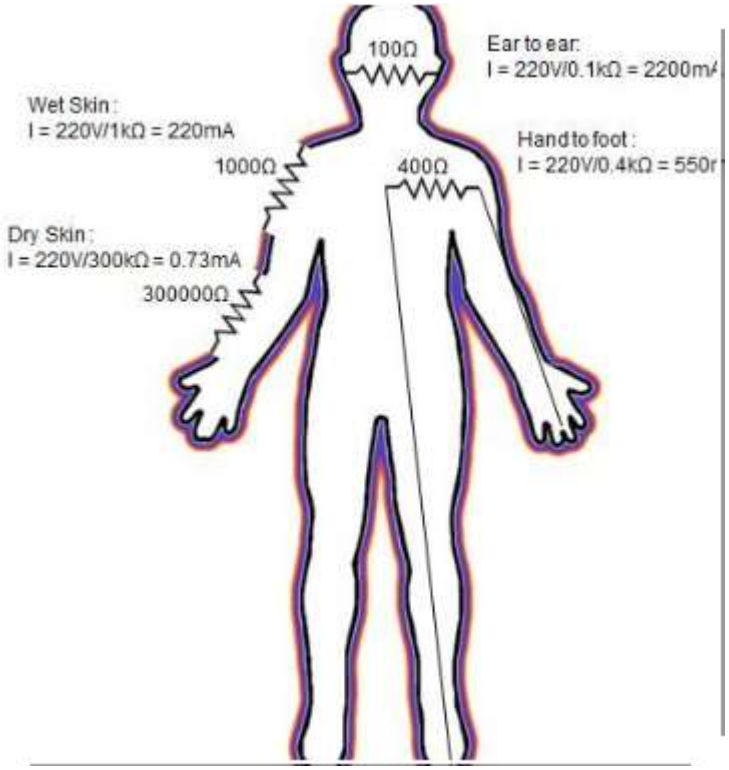
Current through body

- Current depends on
  - Voltage
    - AC, especially 50 Hz, is worst
    - But, DC is also dangerous
  - Resistance
    - Skin + body fluid. Skin most important
    - Moisturous skin worst. ”Murare” ...
    - > 80 mA in more than 0.2 seconds can lead to cardiac arrest



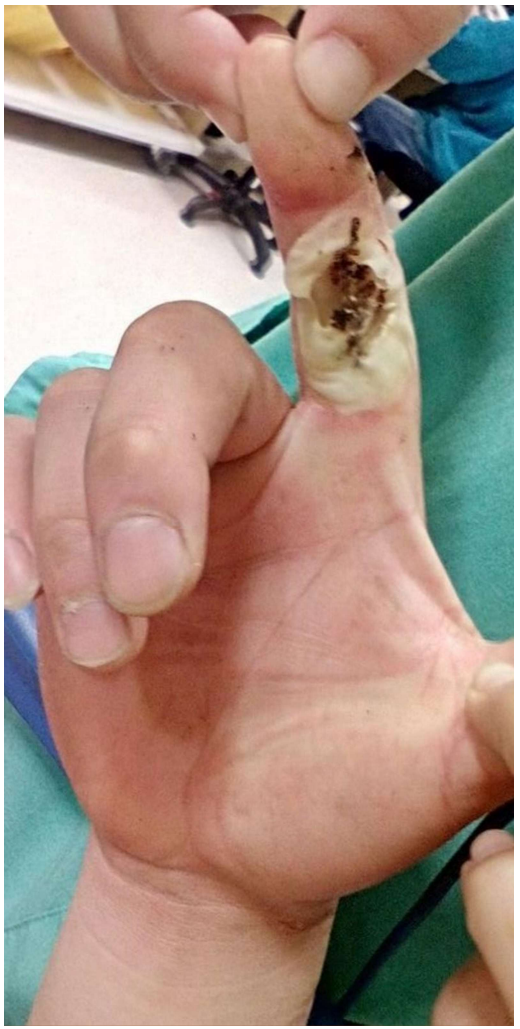
Approximate values for body sensitivity to current





Thus:

- Have the greatest respect for the traction battery!
  - It is dangerous!



Short circuit current

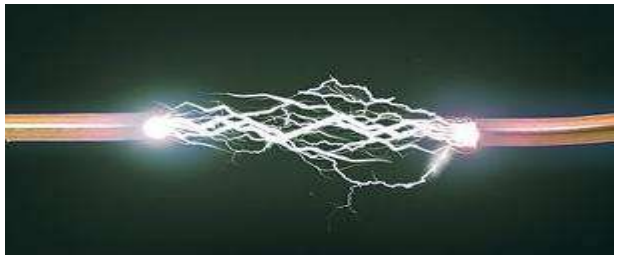
- Very large short circuit currents
  - Low inner resistance
  - Several 1000 Ampére short circuit current
  - Difficult to interrupt due to the inductance of the cables and the lack of zero crossings

Inductance

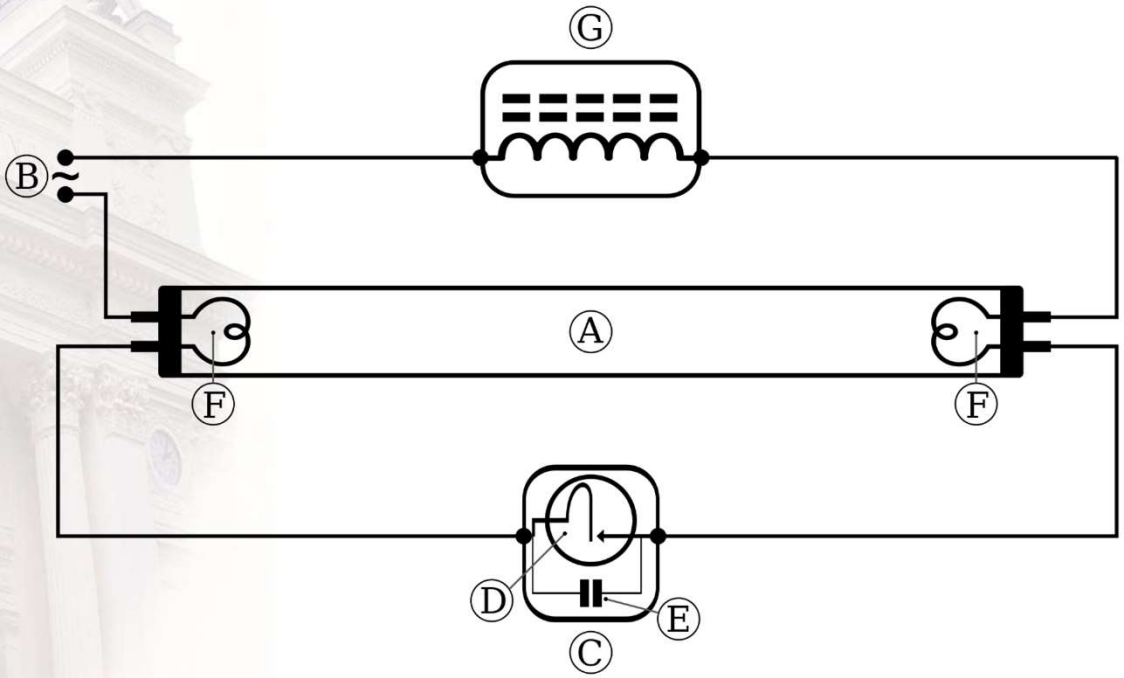
- Stored energy in the magnetic field.
- Unit is Henry
- Single conductor, 1 mikroHenry/m
- Equation u=L*di/dt
- What does that mean?

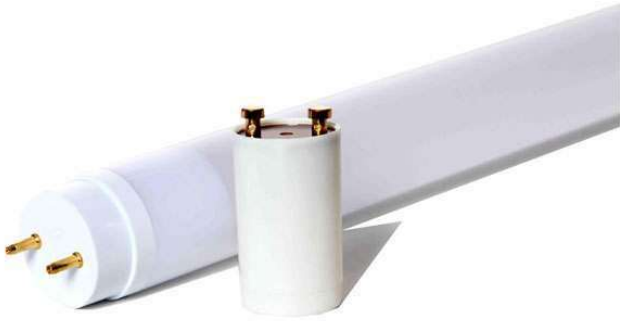
To breake an inductive current

- The inductance sets up a voltage to keep the current going.
- Arcs
- Used in ignition coils and in light tube igniters



Light tube



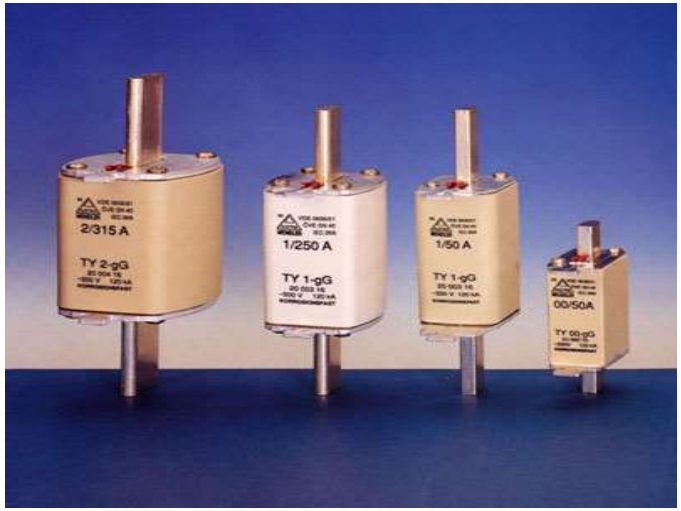


Electric strength of air

- 3 MV/m
- Whe the air is ionized the temperature reaches several 1000 C in a plasma with strong light
- Burns
- Eyes damaged
- Used in welding

Conclusions on braking an inductive current:

- Very large voltages are created that may start sparcs.
- Use fuses, protective clothing, fire extinguisher
- Don’t let it happen!



Power Electronics

- To convert electric energy
- Range: 0 – 1000 MW
- Switching amplifiers

Why Switch?

- Traditional converters have low efficiency, e.g. 25-60 %.
- Switching converters >95 %.

Classes

A

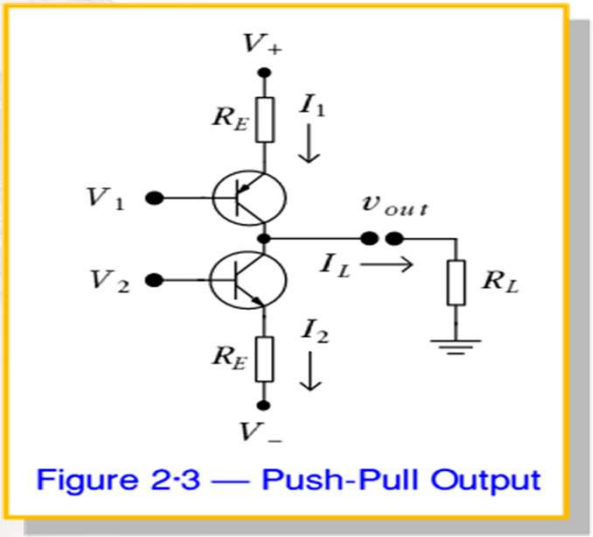
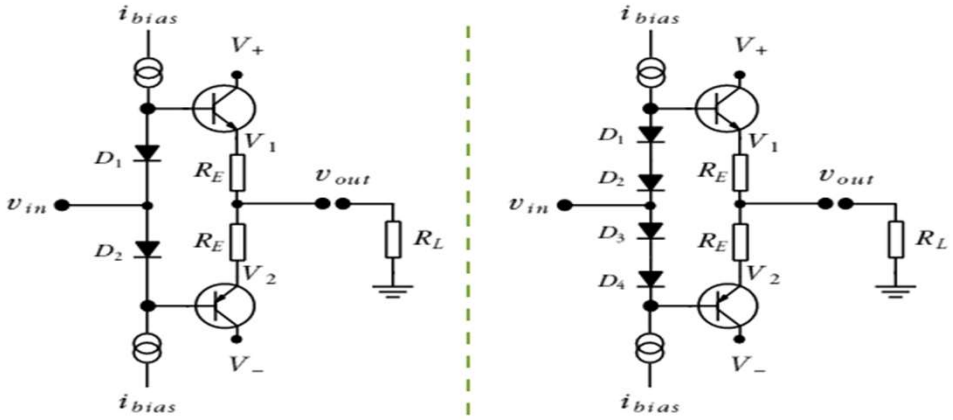


Figure 2·3 — Push-Pull Output

20 – 25%

B och AB

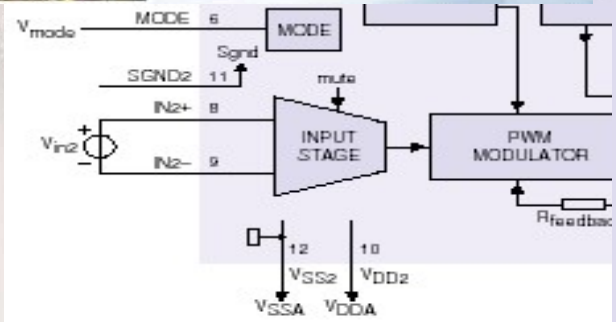


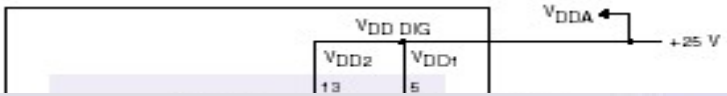
2·4a Class B 2·4b Class AB

Figure 2·4 — Class B and AB Power stages

60 %

Class D Audio Amplifiers



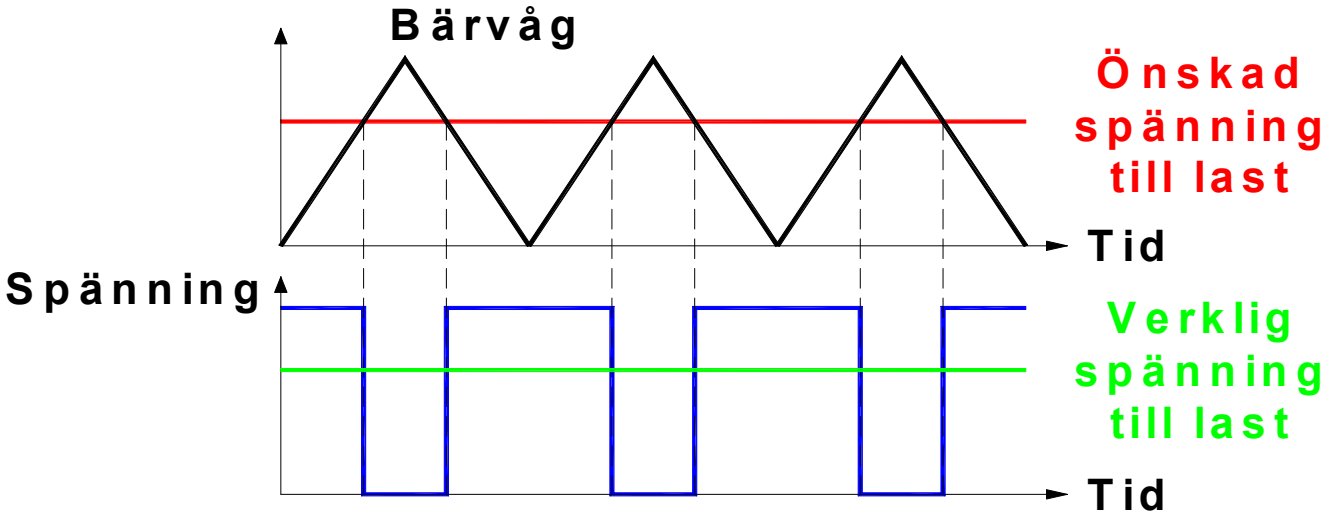


Features

- Power ranges from 20 to 150 W (up to 400 W with application support)
- Excellent power efficiency (≤ 95%)
- Good EMC performance
- Excellent THD (0.01%)
- Symmetrical supply between 15 - 30 V
- Internal oscillator:
  - frequency adjustable between 200 and 600 kHz
  - can be overridden by an external clock (tracking option)
- Output stage protected against short circuit and overheating
- Simple SE and BTL applications
- Few external components
- Asymmetrical supply possible for BTL configurations (with application support)
- Powerpath ICs in Sil17P and HSOP24 Power SMD package

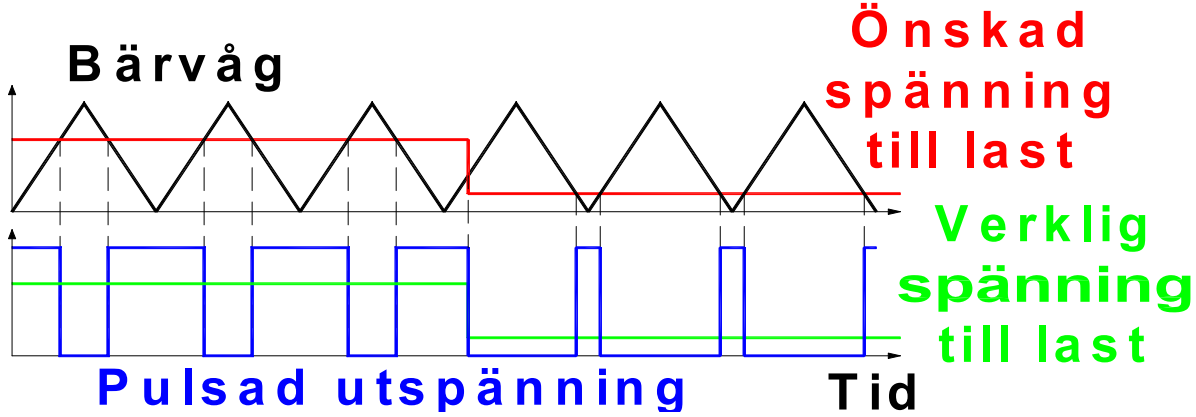
Modulation

- PWM



PWM

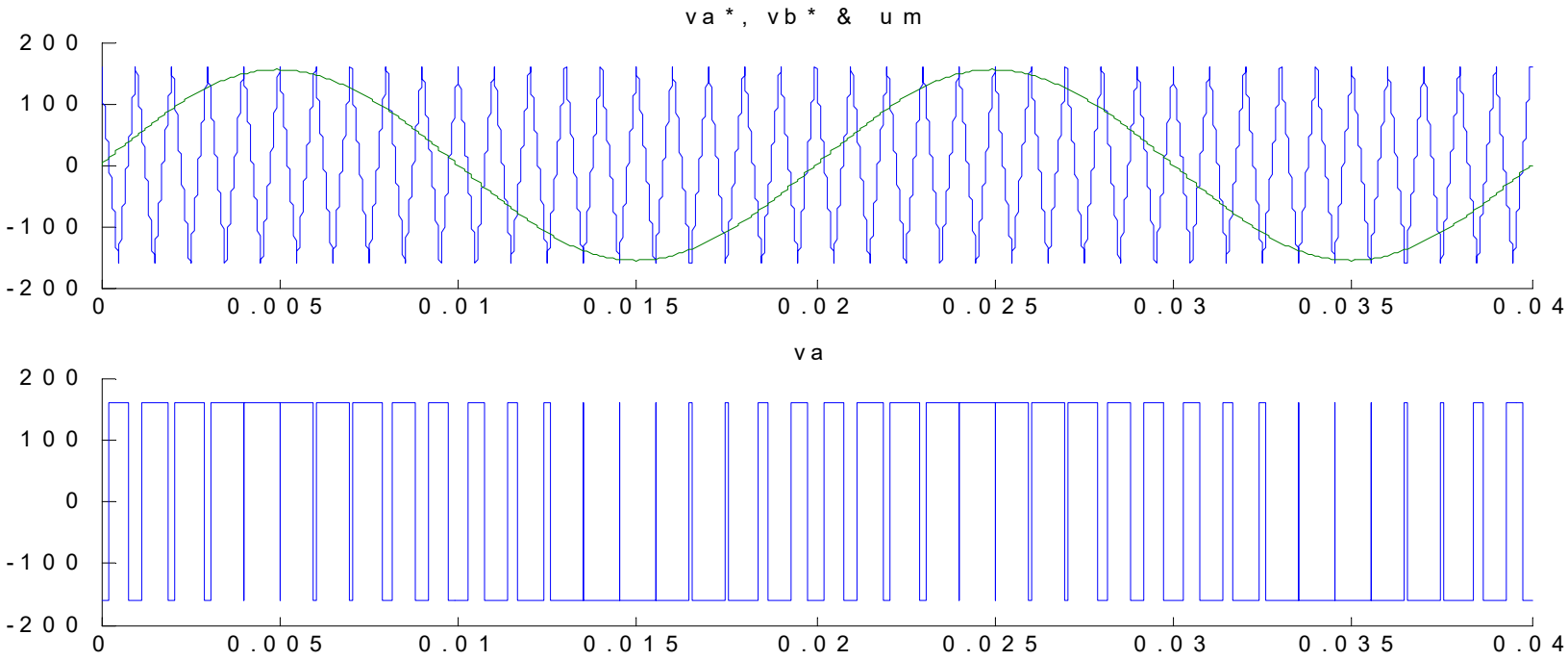
- A variable voltage is created with a pulse width / pulse period.



PWM in Car

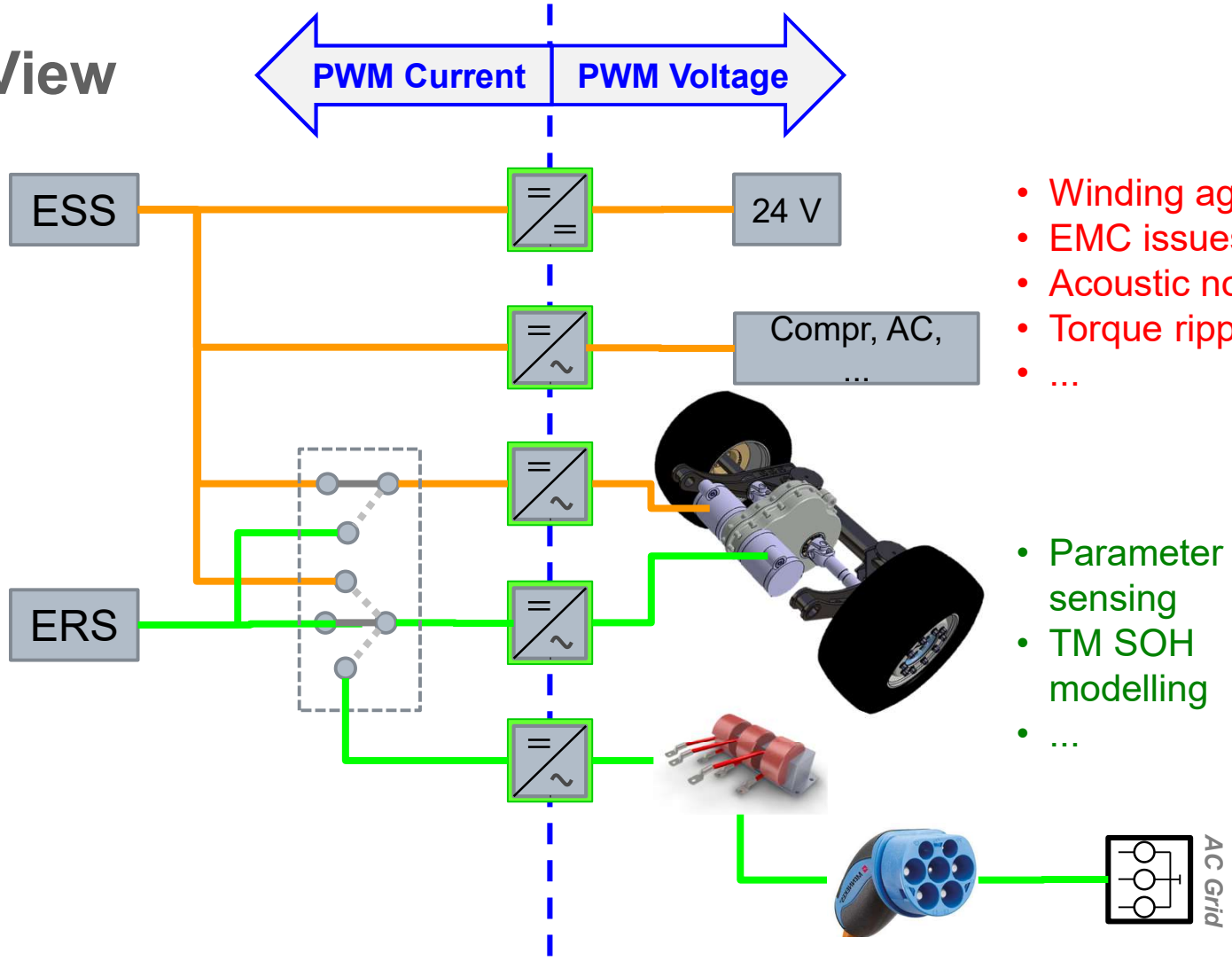
- Long cables
- Square voltages contain wide spectrum
- Noise generated
- Can be heard in the radio ...

PWM


va*, vb* & um
200
100
0
-100
-200
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
va
200
100
0
-100
-200
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04

System View

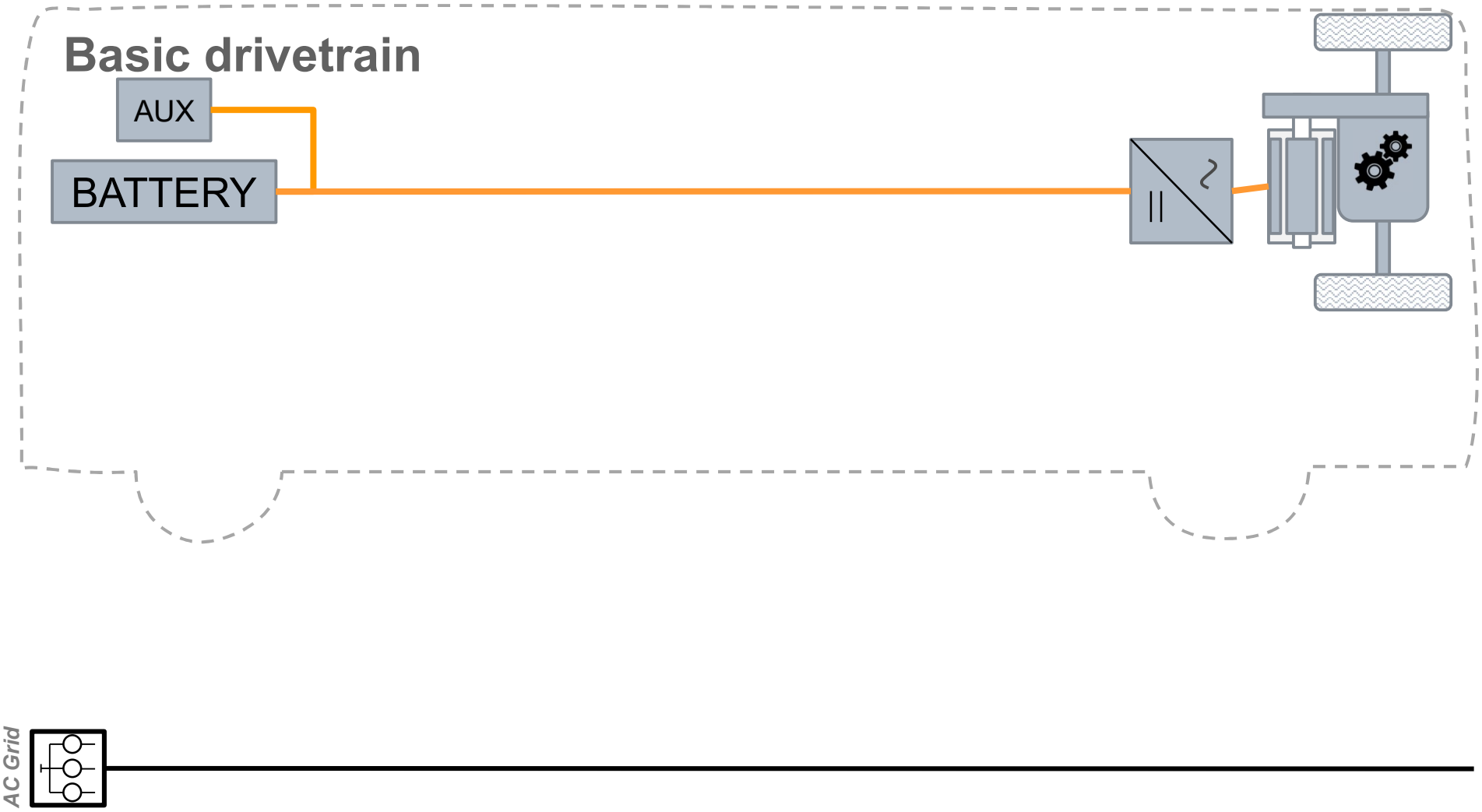
- Losses
- EMC issues
- Harmonics
- System design requirements
- ...



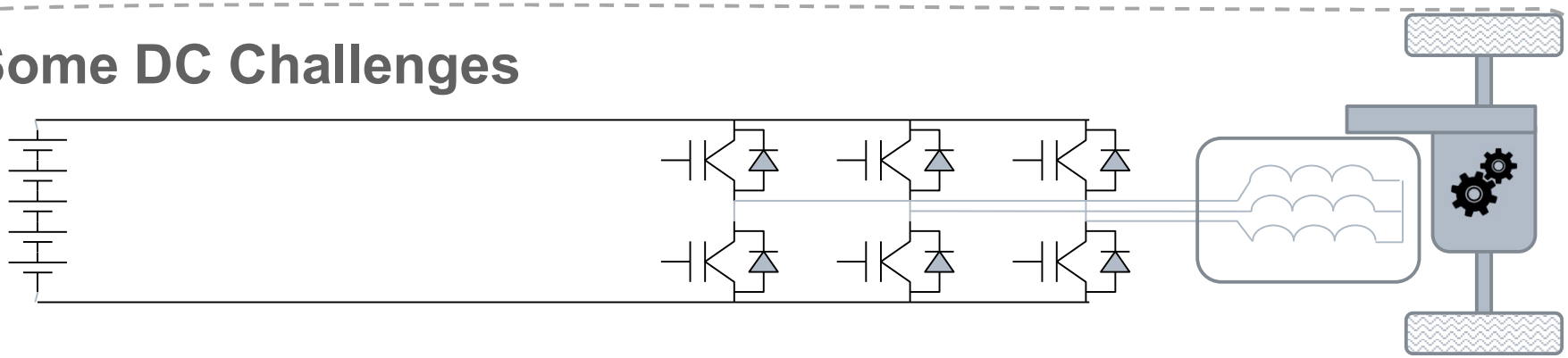
- Winding ageing
- EMC issues
- Acoustic noise
- Torque ripple
- ...

- Parameter sensing
- TM SOH modelling
- ...

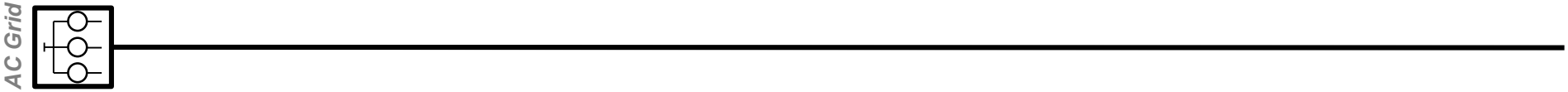
- Parameter sensing
- ESS SOH modelling
- ...


Basic drivetrain
AUX
BATTERY
AC Grid

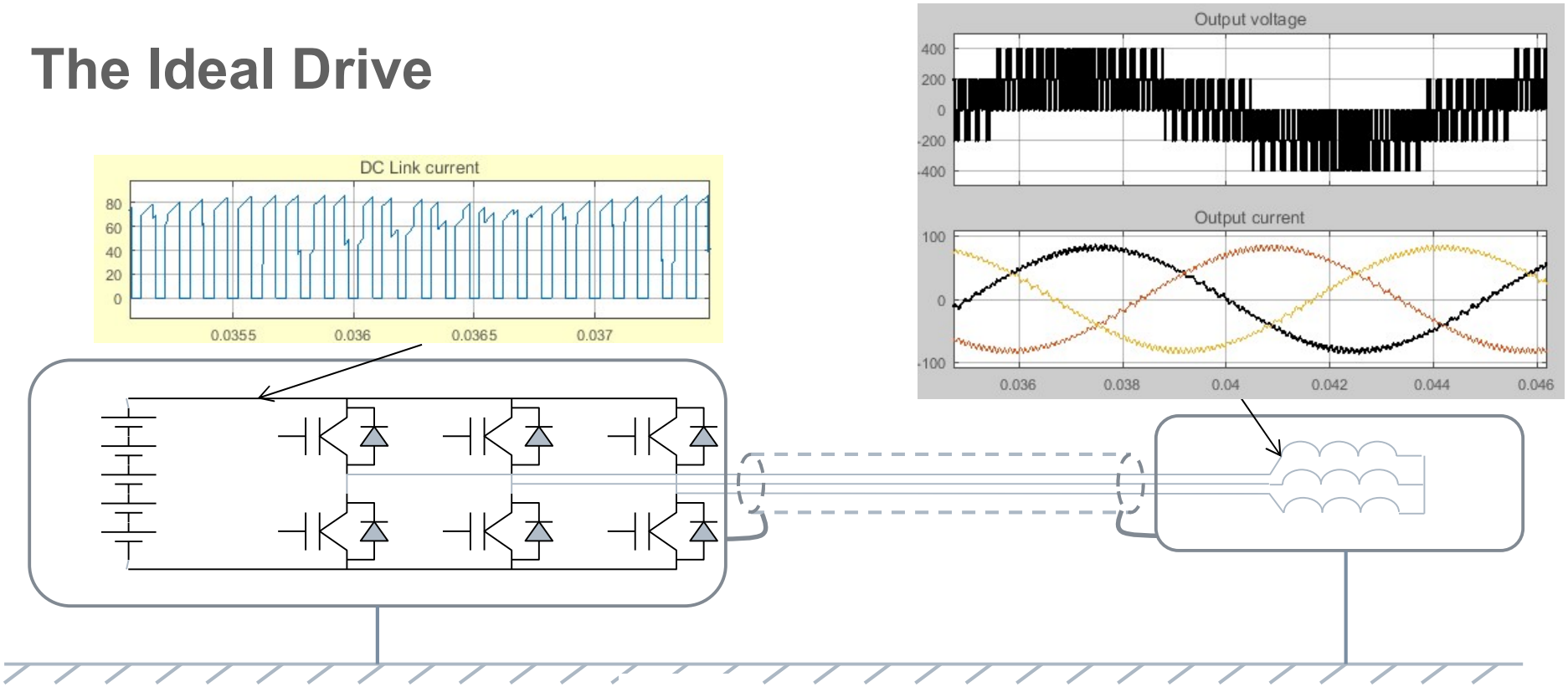
Some DC Challenges



- Isolations fault currents (Battery to Chassis)
- Limit the DC link current ripple



The Ideal Drive



Conclusions on PWH & Safety

- Even if the average voltage is low …
- … the instantaneous voltage is still high
- Be careful!