EnInnov2012

Electric Mobility and Smart Grids: Cost-effective Integration of Electric Vehicles with the Power Grid

Gerald Glanzer
Department of Electronics
FH JOANNEUM - University of Applied Sciences
AUSTRIA
gerald.glanzer@fh-joanneum.at

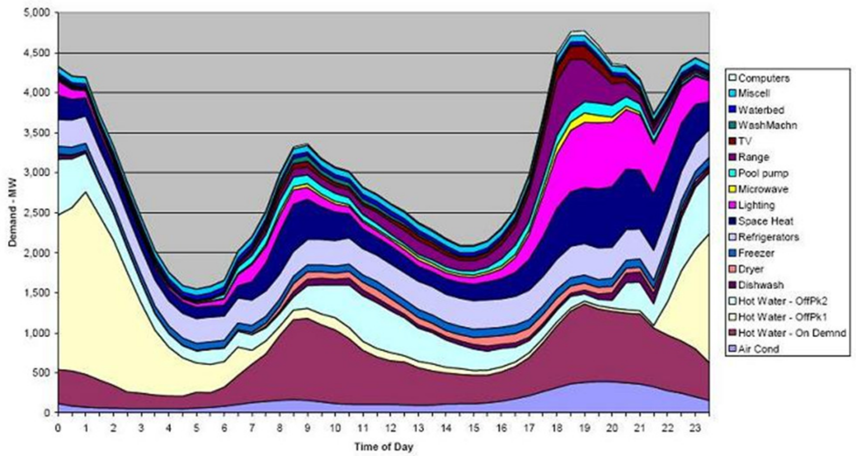
Contents

Introduction

- **Combustion engine based vehicles will be replaced by…**
  - Plug-in hybrid electric vehicles (PHEVs)
  - Pure electric vehicles (EVs)
- **Major objectives**
  - Reduction of emissions (e.g. CO2 gases)
  - Reduction of noise
  - Improvement of the vehicles' energy efficiency
- **Auto manufacturer and power supply companies will be faced with a lot of new technological as well as economic challenges**
- **Therefore, this presentation is focused on cost-effective integration of EVs with the power grid by means of smart charging strategies and integrated on-board chargers**

Charging strategies

- **Normal charging**
  - Simple charging
  - Dual tariff charging based on simple time-of-use (TOU) pricing
- **Smart charging**
  - Algorithm for the calculation of the charging patterns
  - Novel smart power grid infrastructure (combination of a power grid and a communication network)
  - Reduction of electricity costs of consumers



Source: EMET Consultants Pty Ltd

  - Efficient integration of renewable energy sources (low carbon technologies)
  - Vehicle-to-grid (V2G) operation (e.g. prevention of blackout)

Energy control strategies

- **Local energy control strategy**
  - Optimizes local load profiles (e.g. load profiles of households)
  - An advanced metering infrastructure (AMI) is required
- **Global energy control strategy**
  - Optimizes load profiles of large-scale supply areas
  - It is based on a smart power grid infrastructure
- **Centralized smart charging**
  - A central entity (e.g. power supply company) controls the process of charging
  - Impossible or difficult for consumers to influence this process
- **Decentralized smart charging**
  - It is based on the basic principle of a market place
  - Time-dependent price and generation fuel mix information is provided
  - A software unit in the EV controls the process of charging

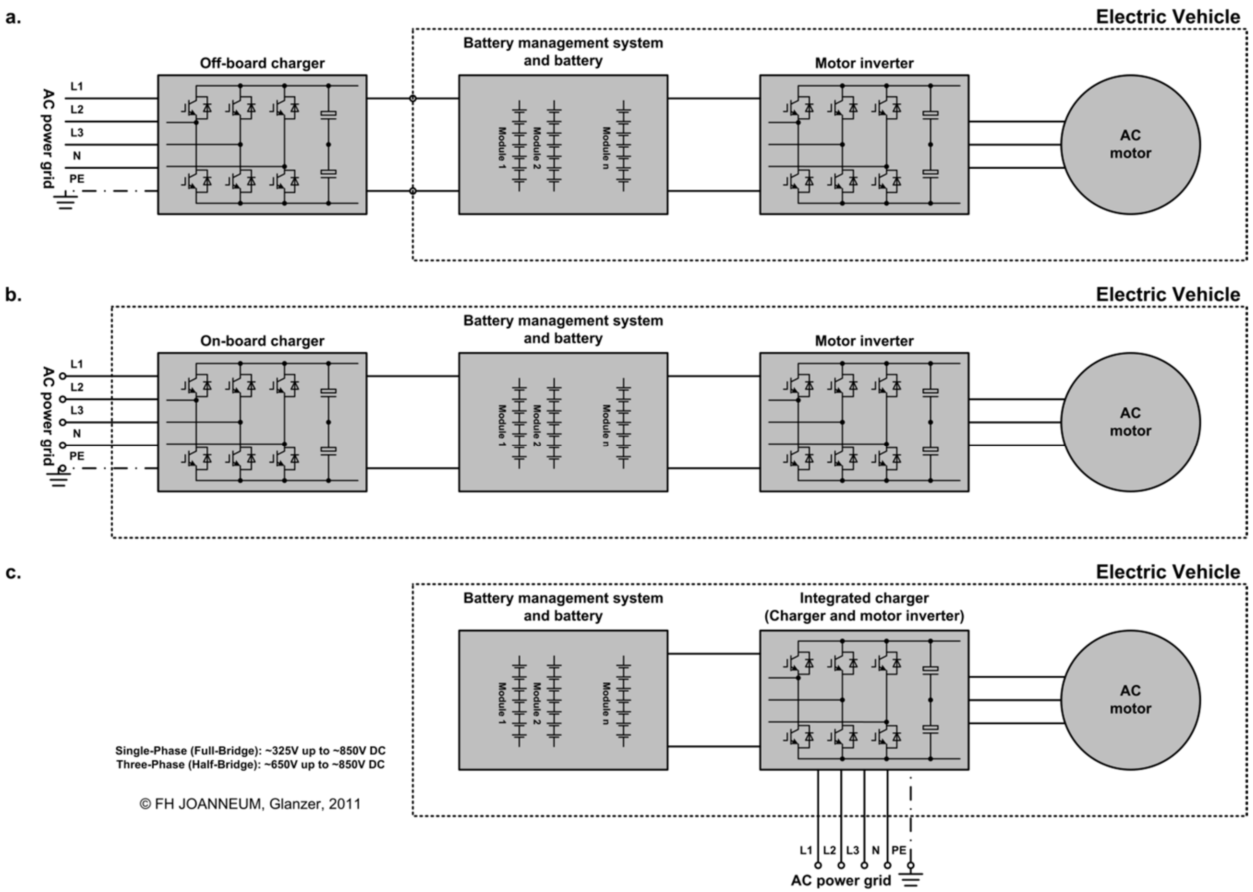
Smart charging infrastructure

- **Smart charging at home**
    - Critical loads
    - Shiftable loads
    - Interruptible loads
  - EVs are classified as shiftable loads
  - Charging will mostly be carried out slowly during off-peak time
  - The electricity price is low or the generation fuel mix is less carbon intensive
- **Public smart charging**
  - Mainly quick charging during daytime
  - The electricity price is higher than average and the generation fuel mix could be more carbon intensive than average. Both parameters depend on:

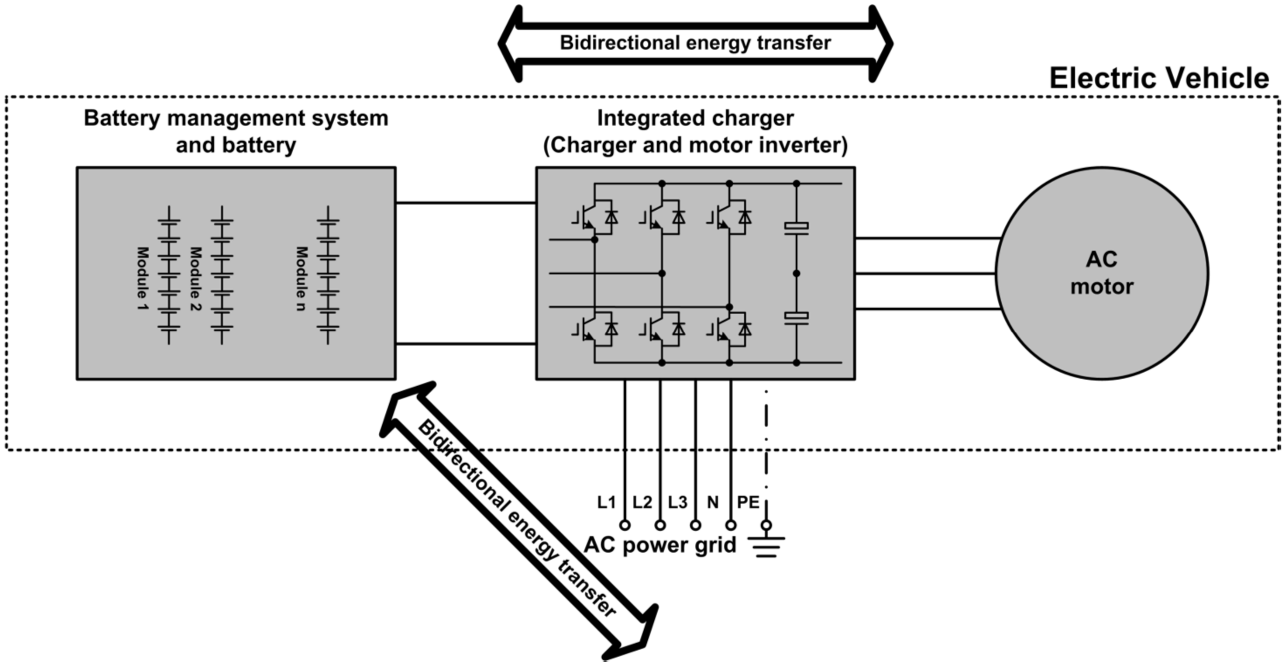
    the moment of charging, the duration of charging and the amount of consumed energy
  - Public charging infrastructure must be set up and maintained!

Charger topologies

- Off-board charger
- On-board charger
- Integrated on-board charger



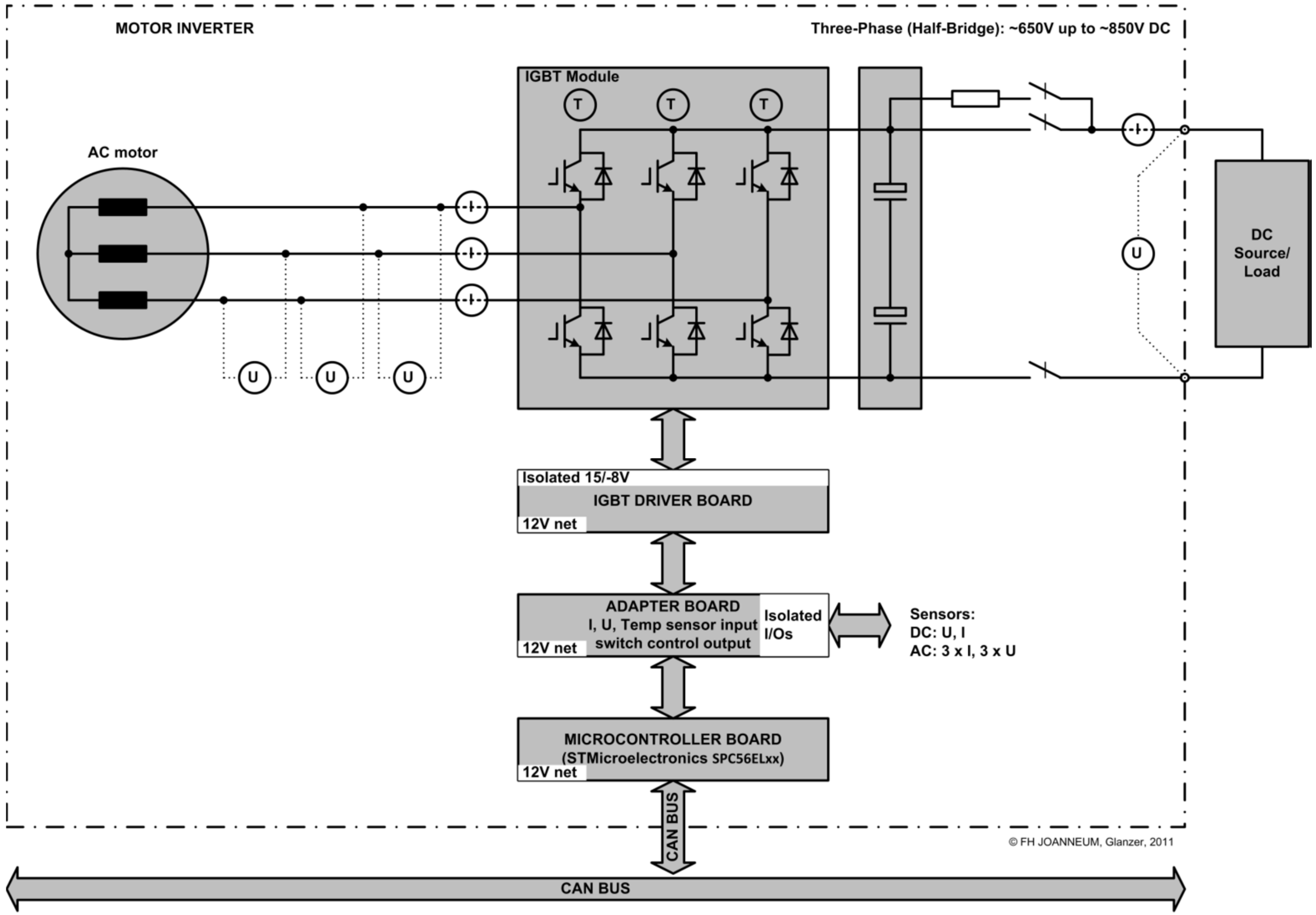
Integrated on-board charger



Single-Phase (Full-Bridge): ~325V up to ~850V DC
Three-Phase (Half-Bridge): ~650V up to ~850V DC

- **The most efficient solution is to integrate the charger in the already existing motor inverter**
- **Minimized manufacturing costs, maintenance costs, size and weight**
- **All power electronics components are concentrated in one single unit**

Motor inverter (sub-concept)

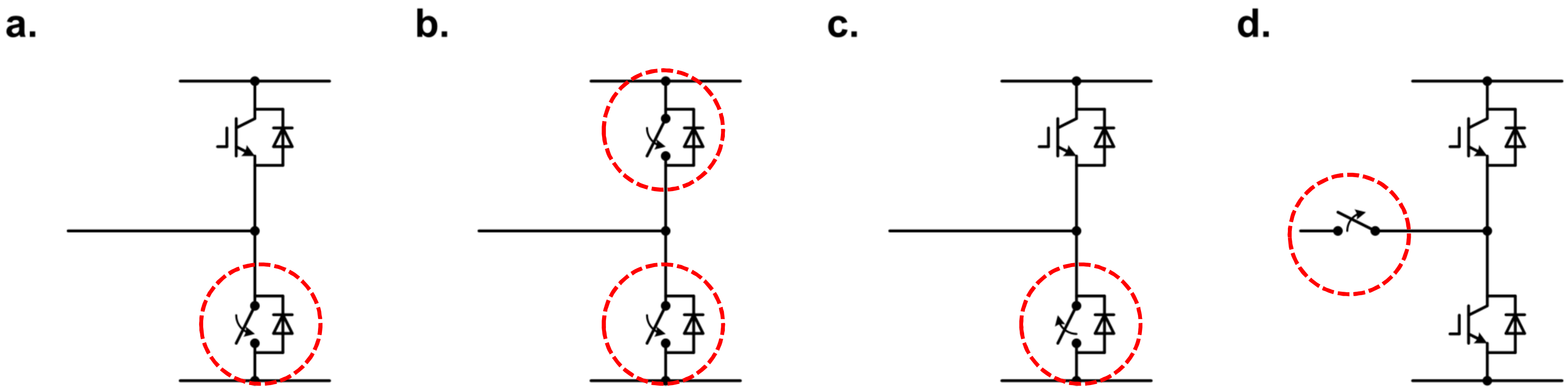


Fail-safe versus fail-operational

- **A charger must be fail-safe (save state)**
- **A motor inverter must be fail-operational (keep it switched on) in some particular driving situations (e.g. overtaking of other vehicles)**
- **Hence, an integrated charger must also be fail-operational**
- **“Limp-Home” strategies:**
  - Fault-tolerant control strategies (3-phase /4-switch, …)
  - Redundant system (multi-phase)
  - …

Faults

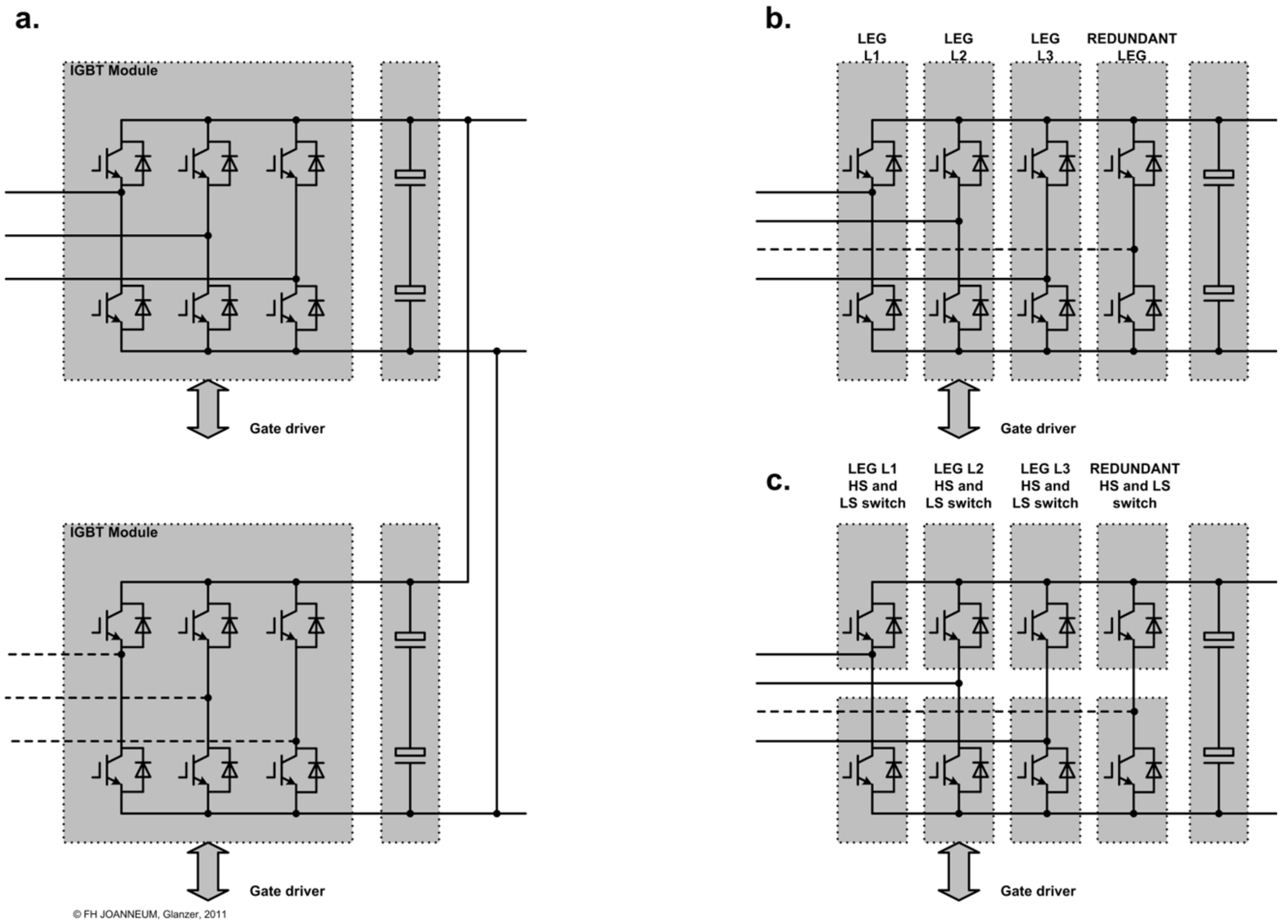
- **Control circuit faults**
- **Power converter circuit faults**
  - DC link capacitors faults
  - Power transistors faults
    - Single switch short circuit
    - Phase leg short circuit
    - Single switch open circuit
    - Single phase open circuit



EnInnov2012

Redundant inverter bridge topologies

- Cascaded inverter topology
- Phase redundant topology
- Double switch redundant topology



Conclusions

- **Sophisticated charging strategies (or energy control strategies) and smart power grids are required to avoid higher peak demands in the load profile**
- **The most promising solution seems to be a global energy control strategy in combination with decentralized smart charging**
- **Further major objectives of smart charging are the reduction of electricity costs of consumers and the efficient integration of renewable energy sources**
- **Bidirectional (V2G) integrated on-board chargers with smart charging functionality are necessary**
- **The costs, weight and size of EVs can be reduced using an integrated on-board charger**
- **This type of charger or inverter must be fail-operational!**

Thank you for your attention!

Questions?