POWER ELECTRONICS CONVERTERS IN ELECTRIC VEHICLES

Part 1

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Introduction

- Electric vehicles (EVs), including battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), plug-in HEVs (PHEVs), fuel-cell electric vehicles (FCEVs), are becoming more commonplace in the transportation sector in recent times.
- The present trend suggests that this mode of transport is likely to replace internal combustion engine (ICE) vehicles in the near future.
- Each of the main EV components has a number of technologies that are currently in use or can become prominent in the future.
- EVs can cause significant impacts on the environment, power system, and other related sectors. In recent times, the EV has been gaining popularity, which has many reasons.

Introduction

- The most significant reason is EVs contribution toward reducing greenhouse gas (GHG) emissions. In 2009, the transportation sector emitted 25% of the GHGs, produced by energy-related sectors. EVs, with enough penetration in the transportation sector, are expected to reduce that figure, but this is not the only reason bringing this century-old and once-dead concept back to life; this time, it makes it comeback as a commercially viable and available product. As a vehicle, an EV is quiet, easy to operate, and does not need any fuel cost that is associated with conventional vehicles.
- As an urban transport mode, it is highly useful. It does not use any stored energy or cause any emission while idling, is capable of frequent start-stop driving, provides the total torque from the start-up, and does not require any trips to gas stations for filling fuels.
- It does not contribute either to any of the smog that makes city's atmosphere highly polluted.
- The instant torque in an EV makes its performance highly preferable for participating in motor sports. The quietness and low infrared signature gives it value for military use as well.

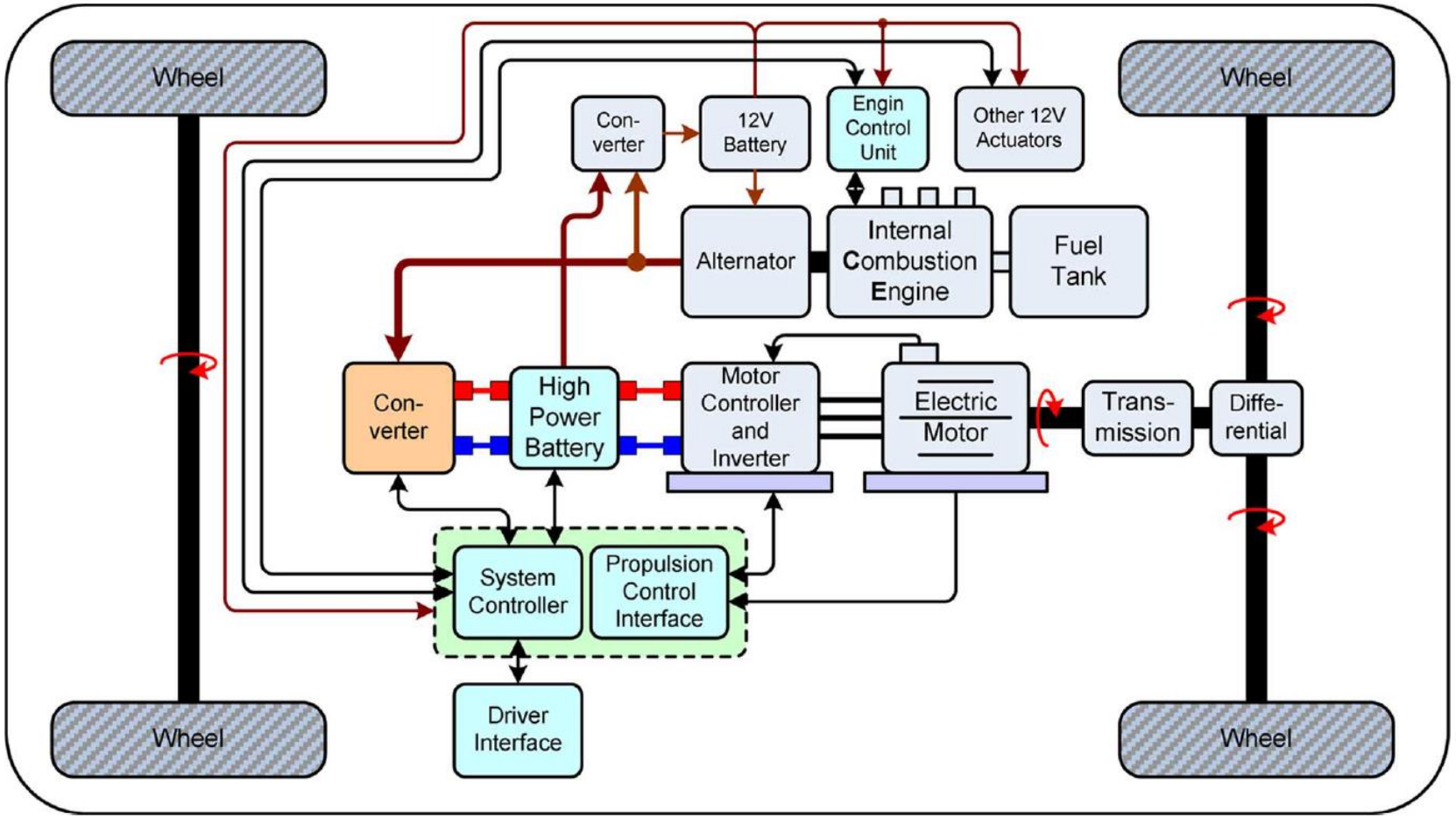
Introduction

- The idea to employ electric motors to drive a vehicle surfaced after the innovation of the motor itself. From 1897 to 1900, EVs had become 28% of the total vehicles and were preferred over the ICE ones. But the ICE types gained momentum afterward, and with very low oil prices, they soon conquered the market, became much more mature and advanced, and EVs got lost into oblivion. A chance of resurrection appeared in the form of the EV concept from General Motors, which was launched in 1996, and quickly became very popular. Other leading carmakers, including Ford, Toyota, and Honda, brought out their own EVs as well.
- Toyota's highly successful Prius, the first commercial HEV, was launched in Japan in 1997, with 18,000 units sold in the first year of production. Today, almost none of those twentieth century EVs exist; an exception could be made for the Toyota Prius, still going strong in a better and evolved form. Now the market is dominated by Nissan Leaf, Chevrolet Volt, and Tesla Model S, whereas the Chinese market is in the grip of BYD Auto Co., Ltd (Xi'an National Hi-tech Industrial Development Zone, Xi'an, China).

Types of electric vehicles

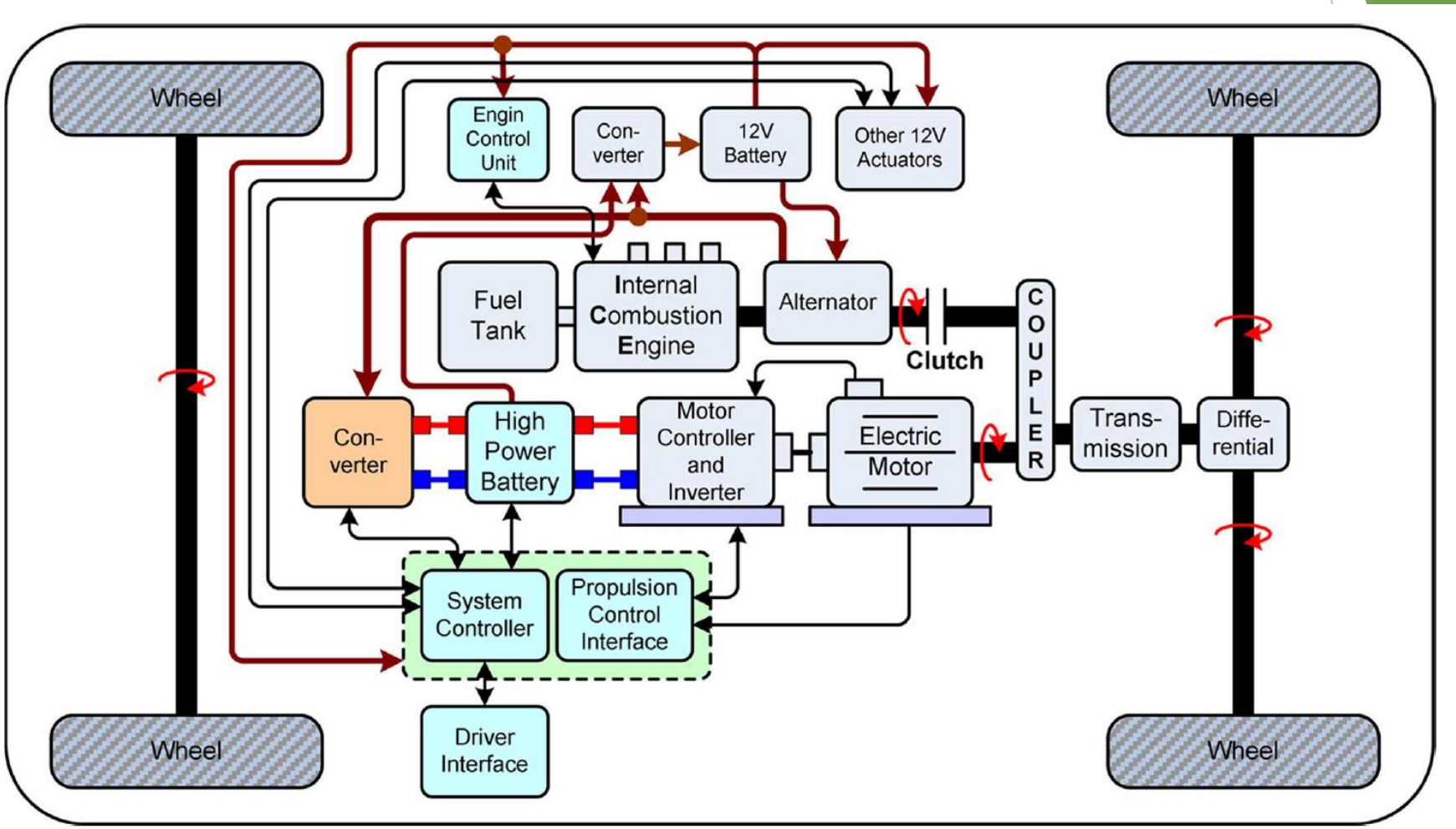
- EVs can be considered a combination of different subsystems and technologies.
- EVs can run solely on electric propulsion, or they can have an ICE working alongside it. Having only batteries as an energy source constitutes the basic kind of EVs, but there are kinds that can employ other energy source modes. These can be called HEVs. The International Electro-technical Commission's Technical Committee 69 (Electric Road Vehicles) proposed that vehicles using two or more types of energy sources, storages, or converters can be called as an HEV as long as at least one of those provides electrical energy.
- This definition makes a lot of combinations possible for HEVs such as ICE and battery, battery and flywheel, battery and capacitor, and battery and fuel cell (FC). Therefore, the common population and specialists both started calling vehicles with an ICE and electric motor combination as HEVs, battery and capacitor ones as ultra-capacitor (UC)-assisted EVs, and the ones with battery and fuel-cell as FCEVs. These terminologies have become widely accepted and according to this norm.
- EVs can be categorized as follows:
  - BEV,
  - HEV,
  - PHEV, and
  - FCEV.

Types of electric vehicles



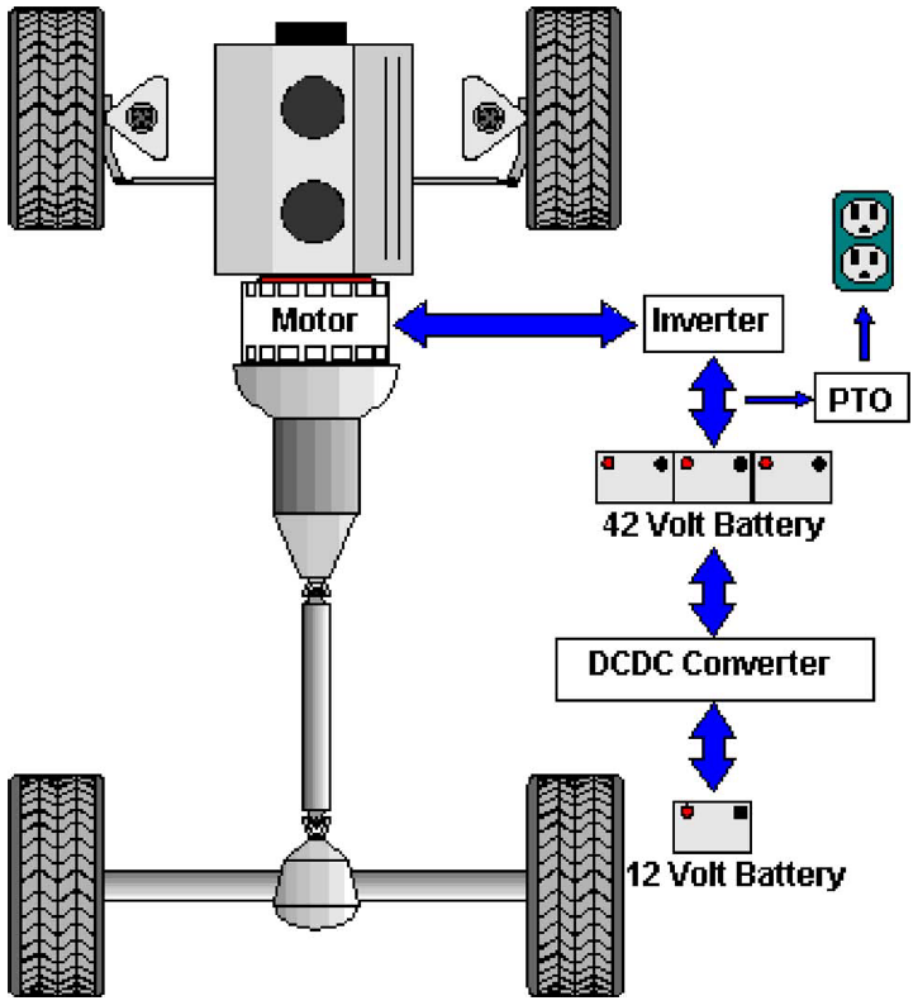
Series hybrid vehicle propulsion system (HEV)

Types of electric vehicles



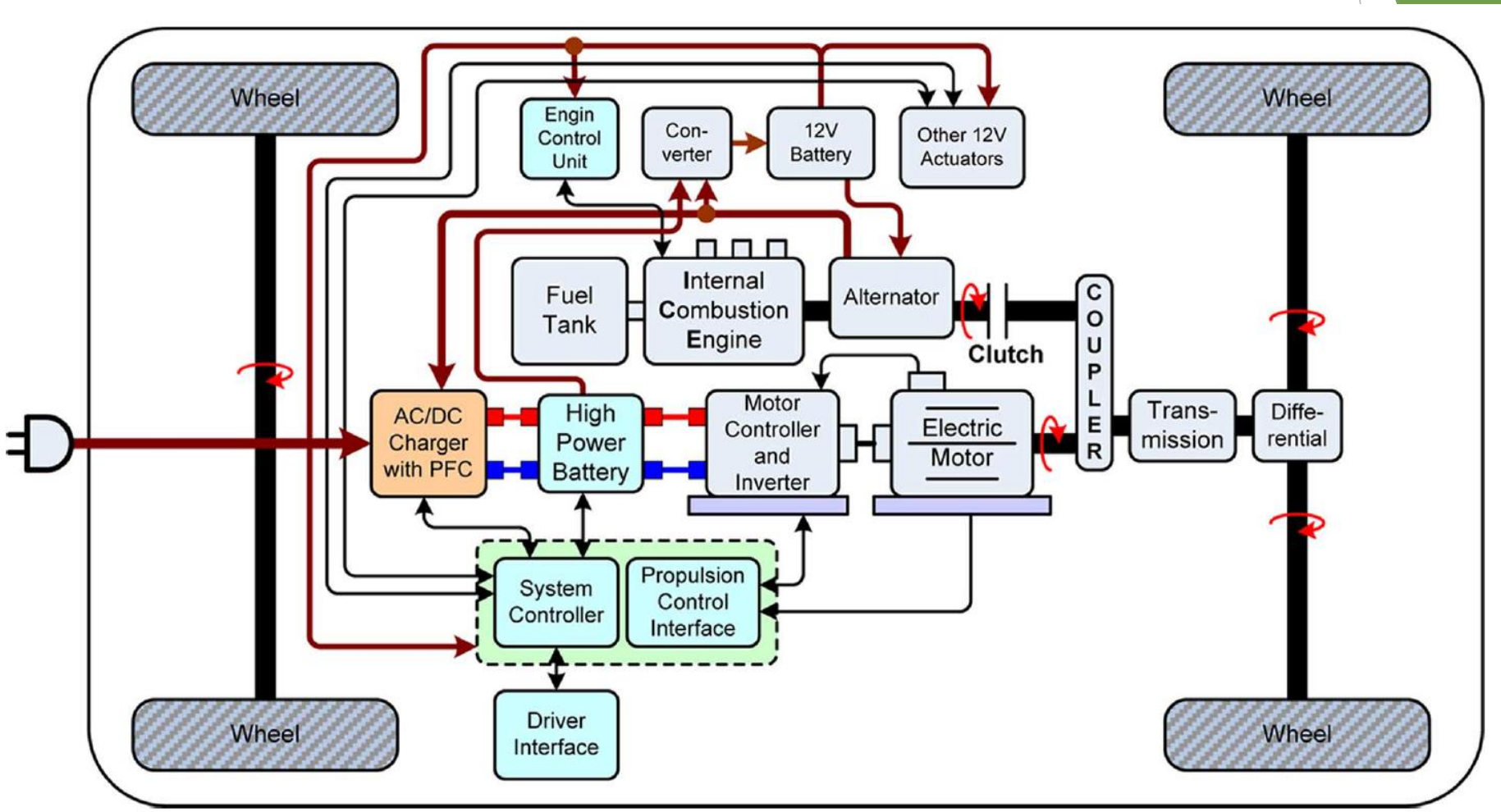
Parallel hybrid vehicle propulsion system (HEV)

Types of electric vehicles



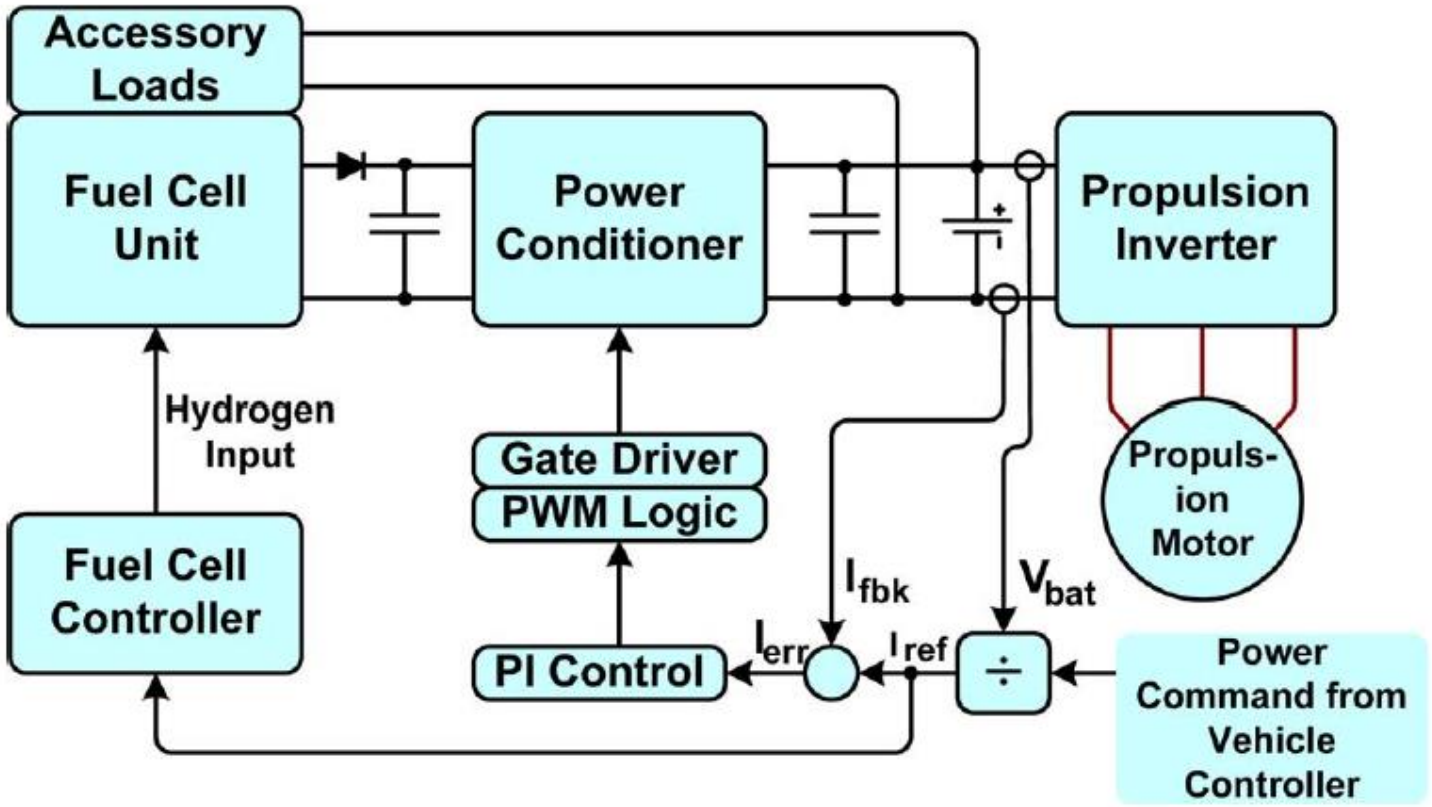
Integrated starter–generator (ISG) based on Energen-10 system architecture (HEV)

Types of electric vehicles



Plug-in hybrid electric vehicle - parallel configuration (PHEV)

Types of electric vehicles



Typical fuel-cell vehicle system (FCEV)

Batteries

- The basic requirement for purely EVs is a portable supply of electrical energy, which is converted to mechanical energy in the electric motor for vehicle propulsion.
- The electrical energy is typically obtained through conversion of chemical energy stored in devices such as batteries and fuel cells.
- Among the available choice of portable energy sources, batteries have been the most popular choice of energy source for EVs since the beginning of research and development programs in these vehicles. The EVs that are available commercially today use batteries as the electrical energy source.
- The desirable features of batteries for EVs applications are high specific power, high specific energy, high charge acceptance rate for both recharging and regenerative braking and long calendar and cycle lifes.
- The major types of rechargeable batteries used or being considered for EVs applications are as follows:

Batteries

- Nickel-metal-hydride (NiMH),
- Lithium-ion (Li-ion),
- Lithium-polymer (Li-poly), and
- Sodium-sulfur.

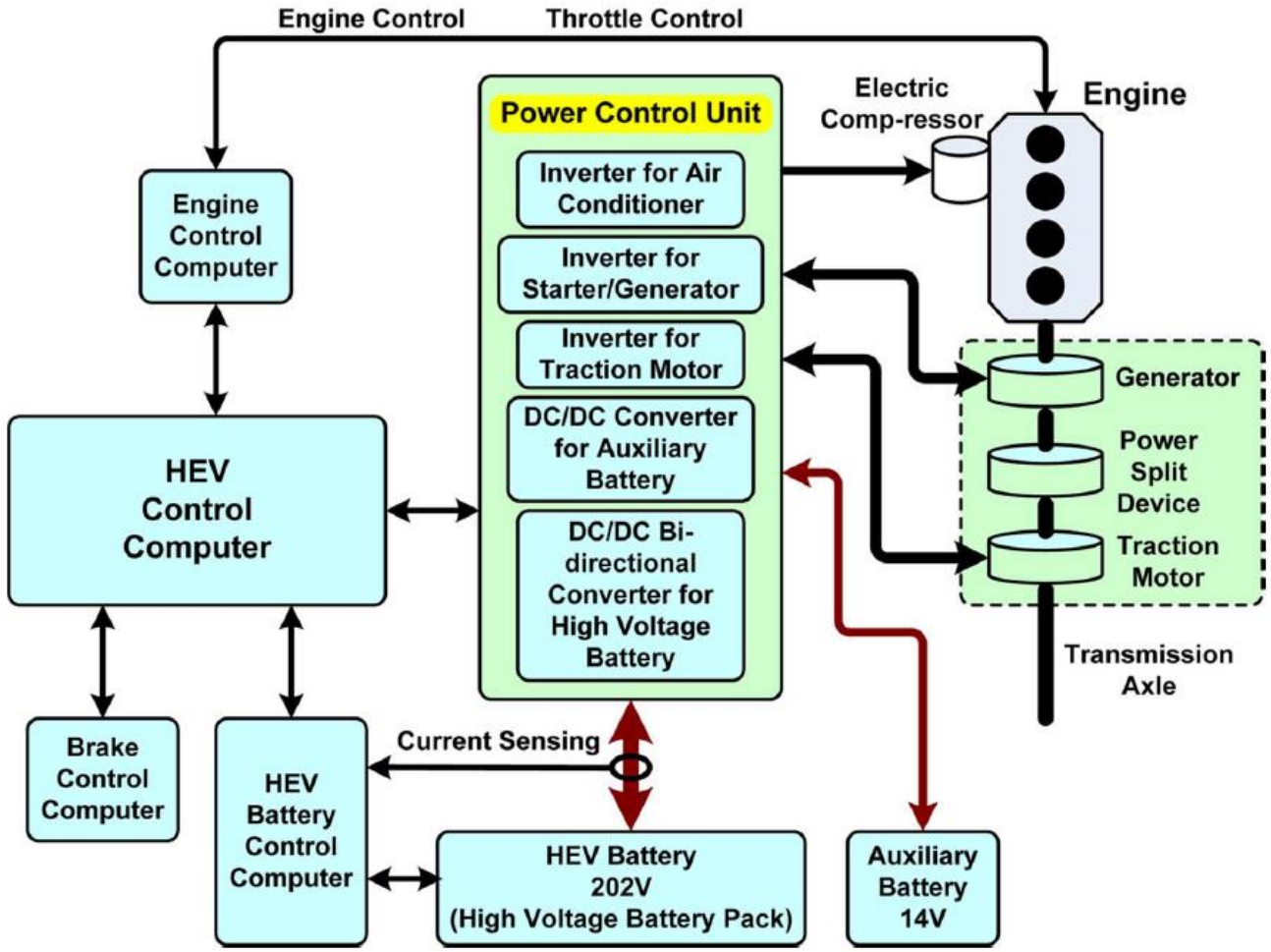
- The Li-ion battery technology is the most promising among the four battery chemistries mentioned above.
- There are several different types of Li-ion battery-pack chemistry available including Li-iron phosphate, Li-titanate, Li-manganese and Li-cobalt.
- The choice for the particular lithium type depends on the type of EV.

Power electronics in electric vehicles

- The power switching devices, electric motors, and associated control systems and components play a key role in bringing EVs to market with reliability and affordability.
- The power electronic system should be efficient to improve the range of the EVs and fuel economy.
- The selection of power semiconductor devices, converters/inverters, control and switching strategies, the packaging of the individual units, and the system integration are very crucial to the development of efficient and high-performance EVs.
- In addition to power devices and controllers, there are several other components such as capacitors, inductors, bus bars, thermal systems, etc., that form a major portion of a power electronic unit. The packaging of all these units as one system has significant challenges.

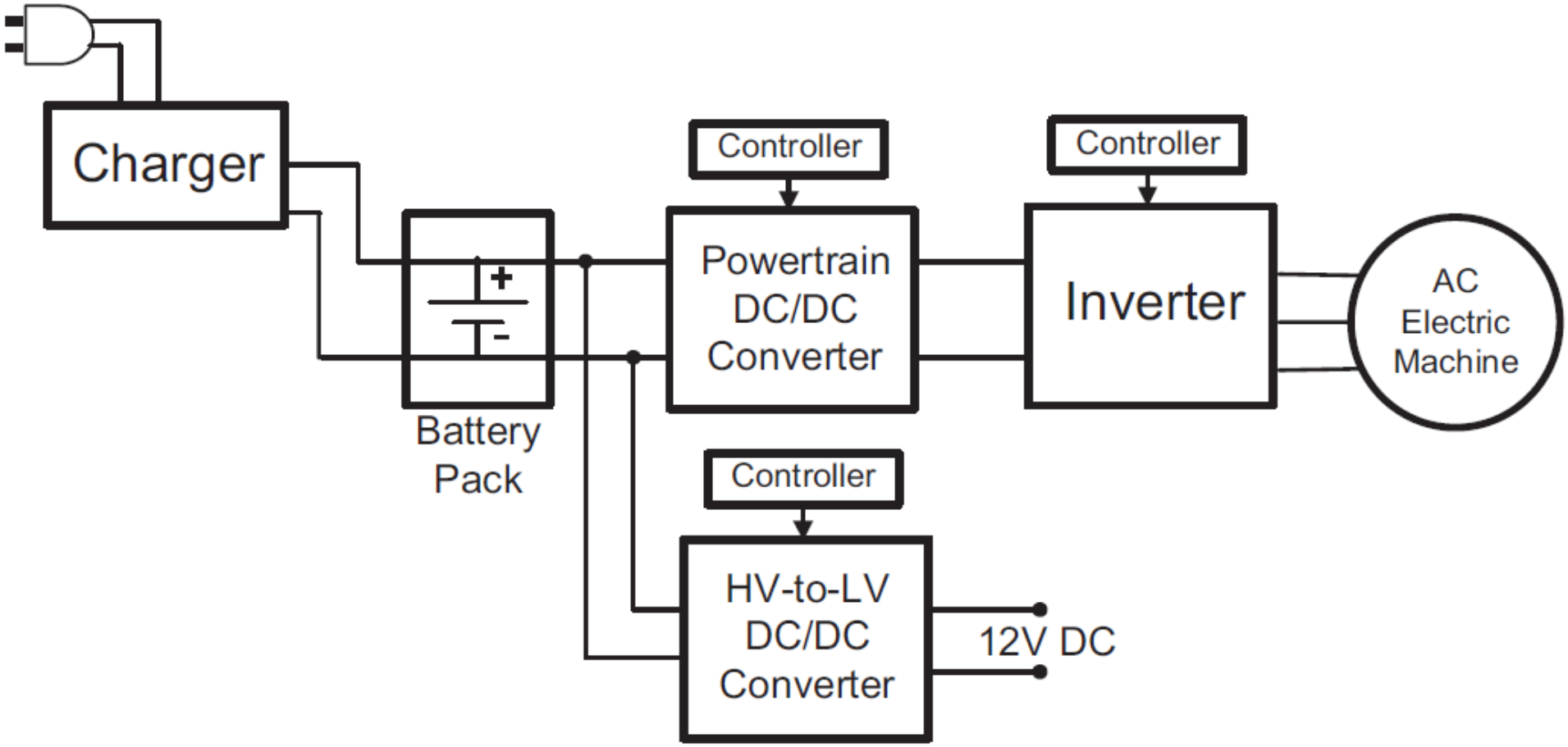
Power electronics in electric vehicles

- Example:



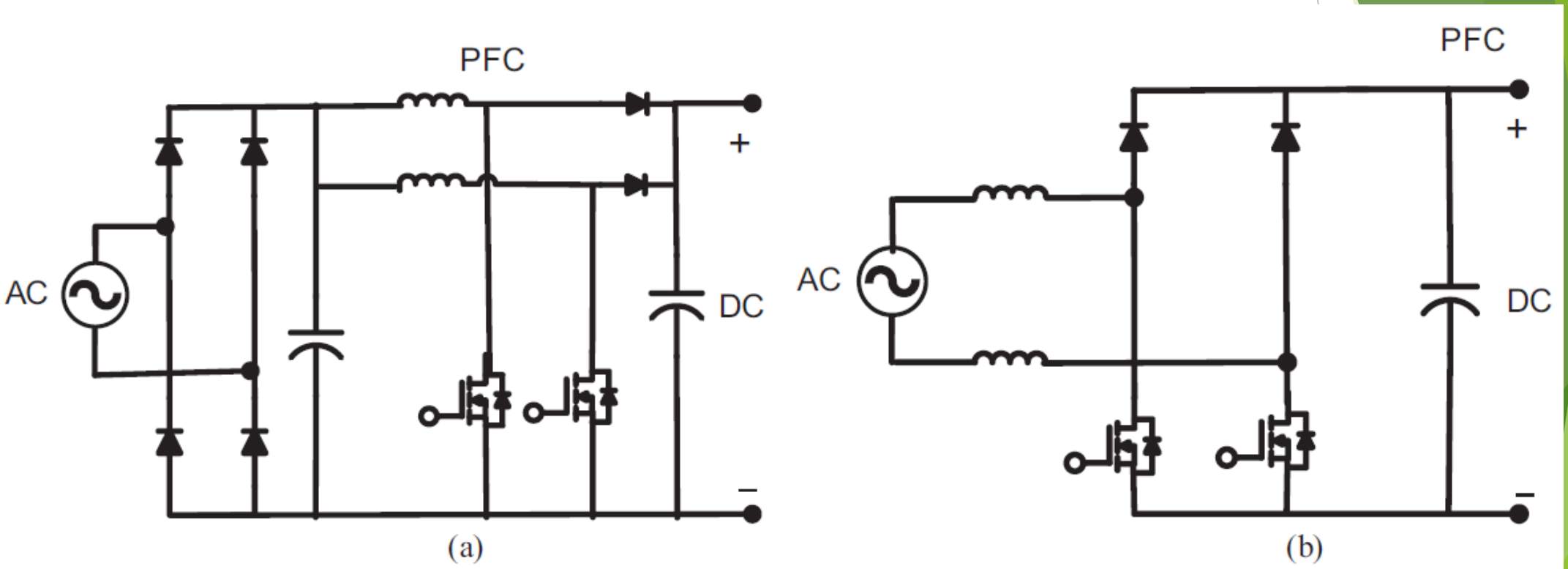
Power control unit (Toyota Hybrid Synergy II)

Power electronics in electric vehicles



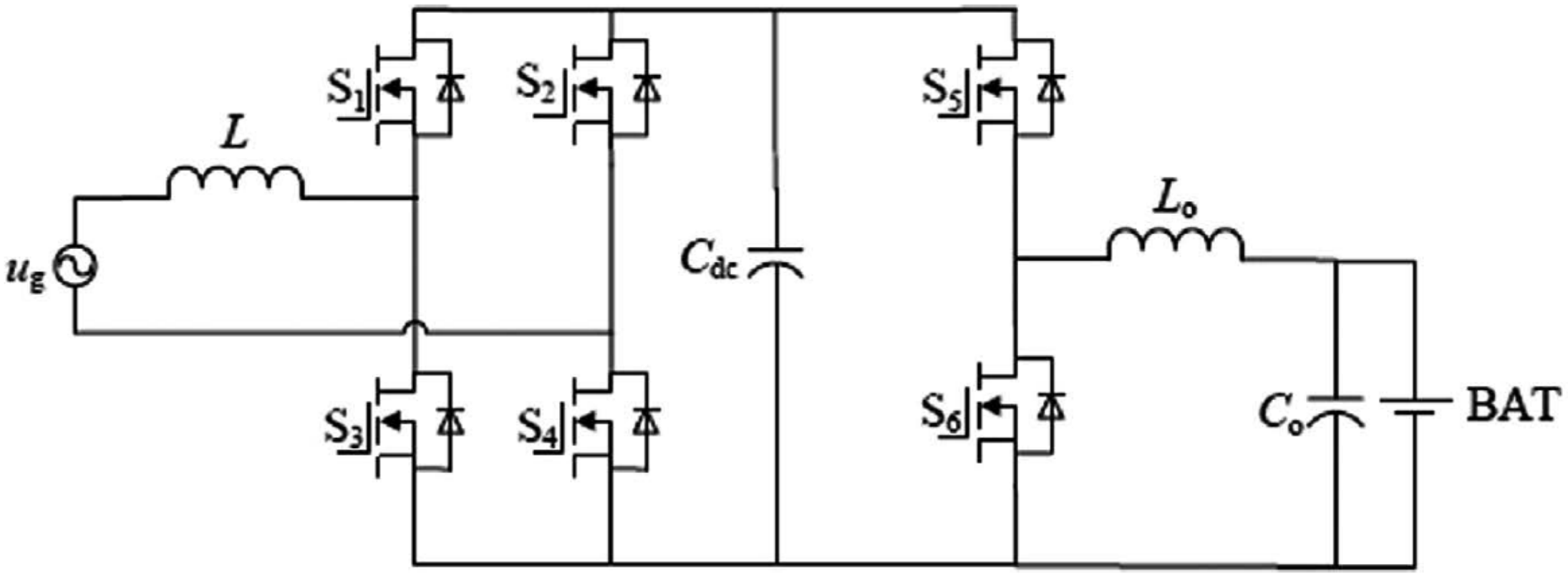
Power electronic converters in an EV electric powertrain

Battery chargers



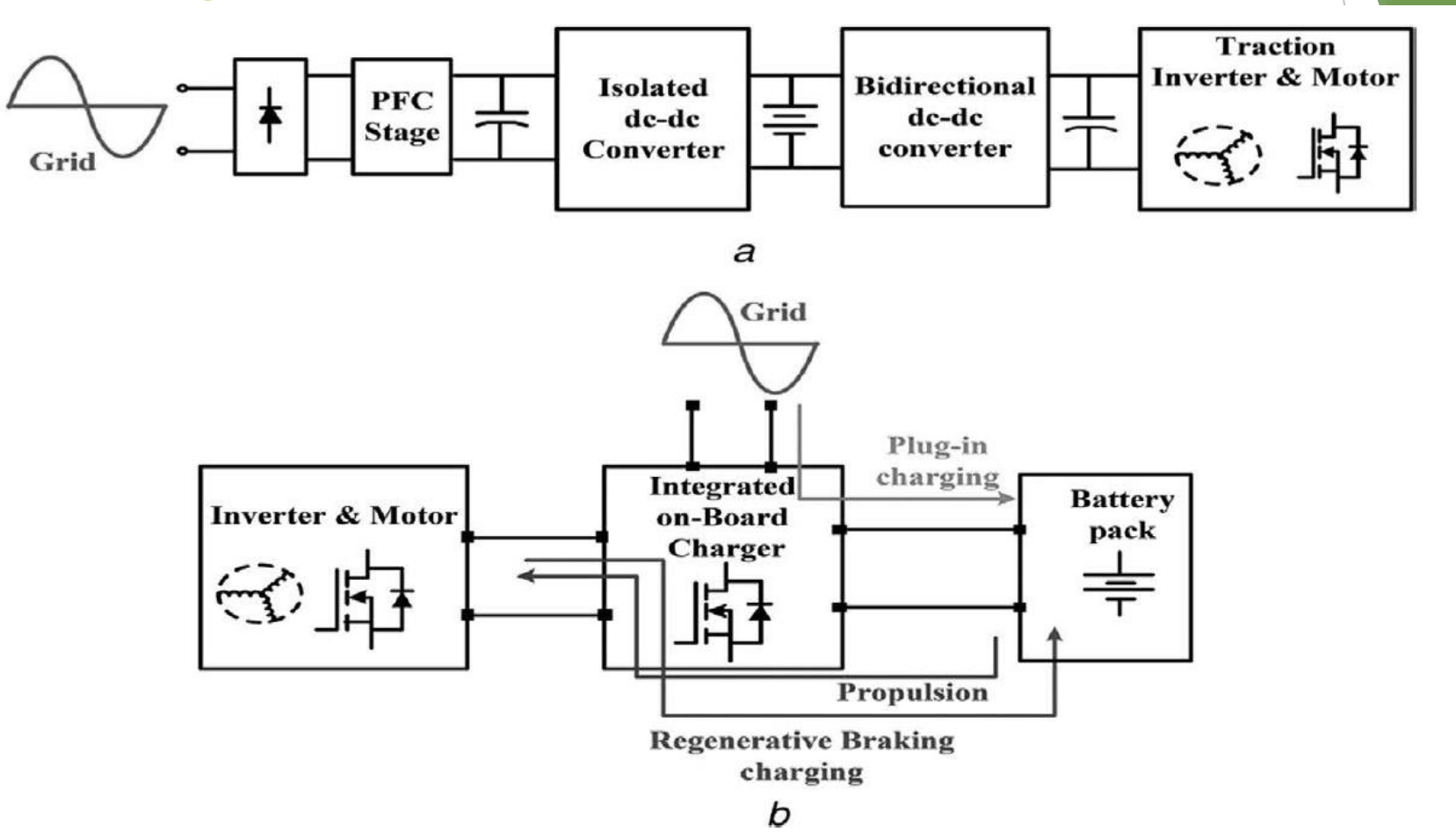
Front-end topologies for on-board battery charger (OBC):
(a) interleaved PFC topology and (b) bridgeless PFC topology

Battery chargers



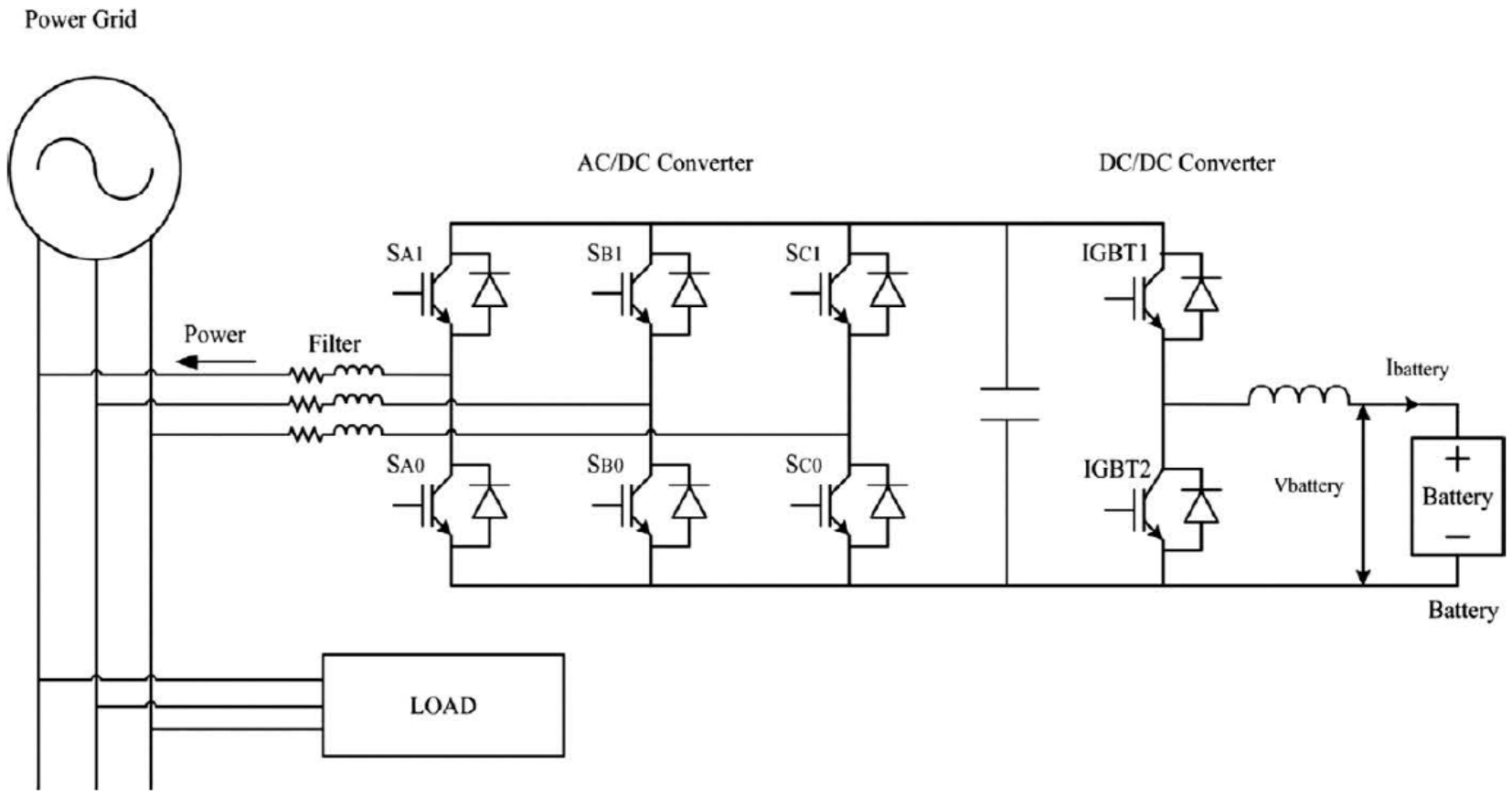
Topology of non-isolated onboard bidirectional charger

Battery chargers



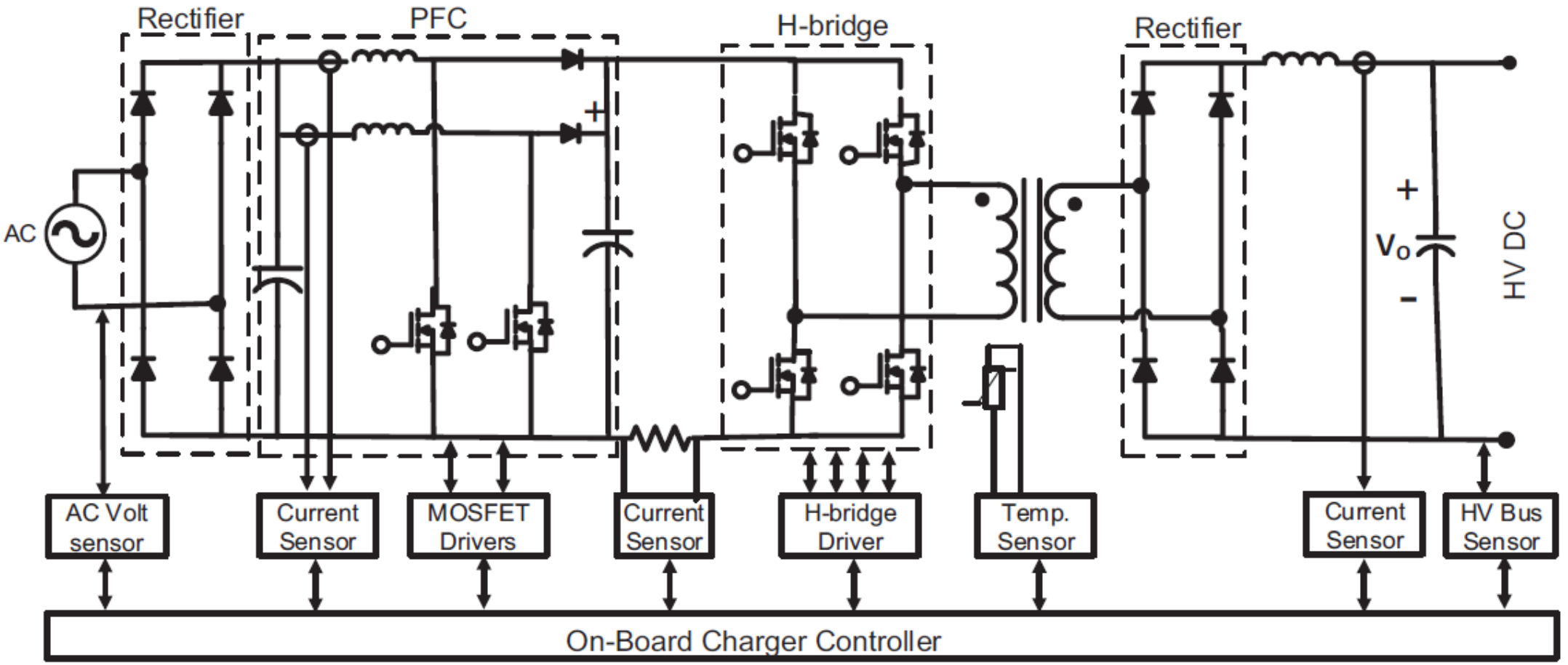
Block diagram of EV battery charging:
(a) with a conventional two-stage electric vehicle battery charger and
(b) with an integrated converter (AC/DC and DC/DC converters)

Battery chargers



A bidirectional flow converter

Battery chargers



OBC circuit topology