INDUSTRY STANDARD

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-safe handling of vehicles with high-voltage system

(For example, all-electric or partly electric drive systems and other high-voltage systems)

Source: Renault

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This industry standard has been produced by BIL Sweden in cooperation with its members as well as concerned authorities, industry organisations, unions and employer associations.

Industry standard for working with electric hybrid and electric vehicles as well as other high-voltage systems, e.g., comfort systems (A/C compressor)

The purpose is to give a description of the industry standard and basic information about handling of vehicles with all-electric or partly electric drive systems according to Swedish regulations.

Preface

Vehicles with all-electric or partly electric drive systems (drivetrain systems) are becoming more common and require both new knowledge about and insight into how they function. This also applies to other high-voltage components that are included in a vehicle.
Repairs and service of vehicles with high-voltage components shall take place according to the manufacturer's instructions. There are special regulations from authorities which are applicable when working with parts of electric high-voltage systems and energy storage (batteries, capacitors, etc.), which means that the work must be performed according to these regulations.
The industry standard links to the National Electrical Safety Board's regulations and general advice (ELSÄK-FS 2006:1) as well as applicable parts of Swedish standard SS-EN 50110-1 when working in electric high-voltage systems. The publication is primarily intended for professionals who want a collective presentation of the rules' application, but may well also be used by the authorities.
The basis for the industry standard are the regulation texts with general advice. In case of deviations, the governing regulations, stipulations, and laws always apply.

Safe handling of vehicles with all-electric or partly electric drive systems

This industry standard is for those who handle vehicles with all-electric or partly electric drive systems with information on:

- how to identify the vehicle
- general description of different electric drive systems
- the different types of electric energy storage (batteries, capacitors, etc.)
- responsibility issues on a work site
- competence issues
- handling of risks

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1. General information

A job shall always be performed in a professional manner, which means that the person shall have documented competence, authorization, knowledge, access to the car manufacturer's instructions for the vehicle in question, as well as the right technical equipment to be able to do the work. The work site shall at least meet the requirements stated in the industry standard.

Identification of vehicles

There is no standard or industry agreement on how symbols shall be used to identify electric and electric hybrid vehicles or how they shall be marked. Every car brand has its own markings. If uncertain, contact the car manufacturer or their representative. *See also supplementary information under item 7 "marking when working on vehicles" page 19).*

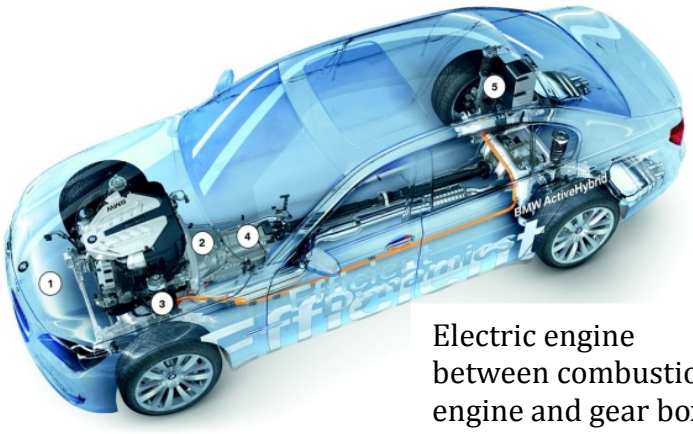
The two main groups electric hybrid and electric vehicles, which are described in this industry standard, differ in the regard that the electric vehicle is always driven by one or several electric motors while an electric hybrid can be driven either by one or several electric motors and/or a combustion engine (range extender), or both at the same time. Common for the two categories is that the vehicles are equipped with a high-voltage system (HV-system) to drive the electric motor/electric motors.

NOTE! This industry standard also applies to other high-voltage components such as A/C compressor, vacuum pumps, etc.

2. General technical information

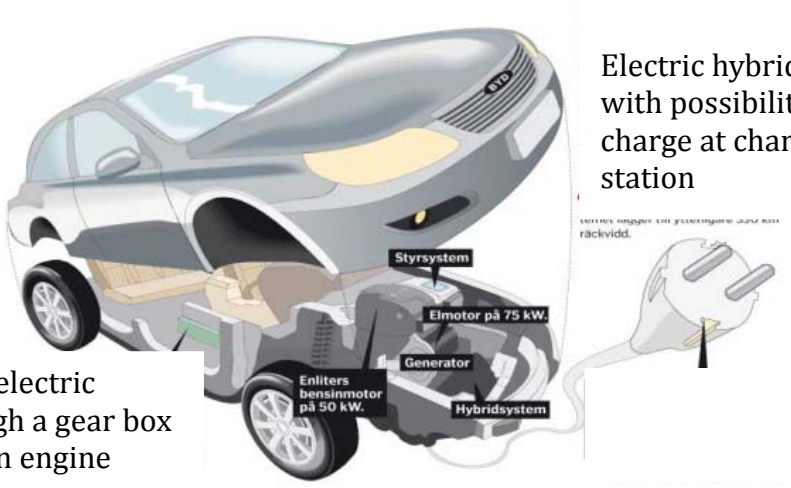
The hybrid technology's main principles

Hybrid cars are available and will be introduced in several different versions. The basis for a hybrid vehicle is a vehicle with double drive systems. Often there is an electric motor in combination with a combustion engine. The figures below show examples of technical solutions that are available on the market.



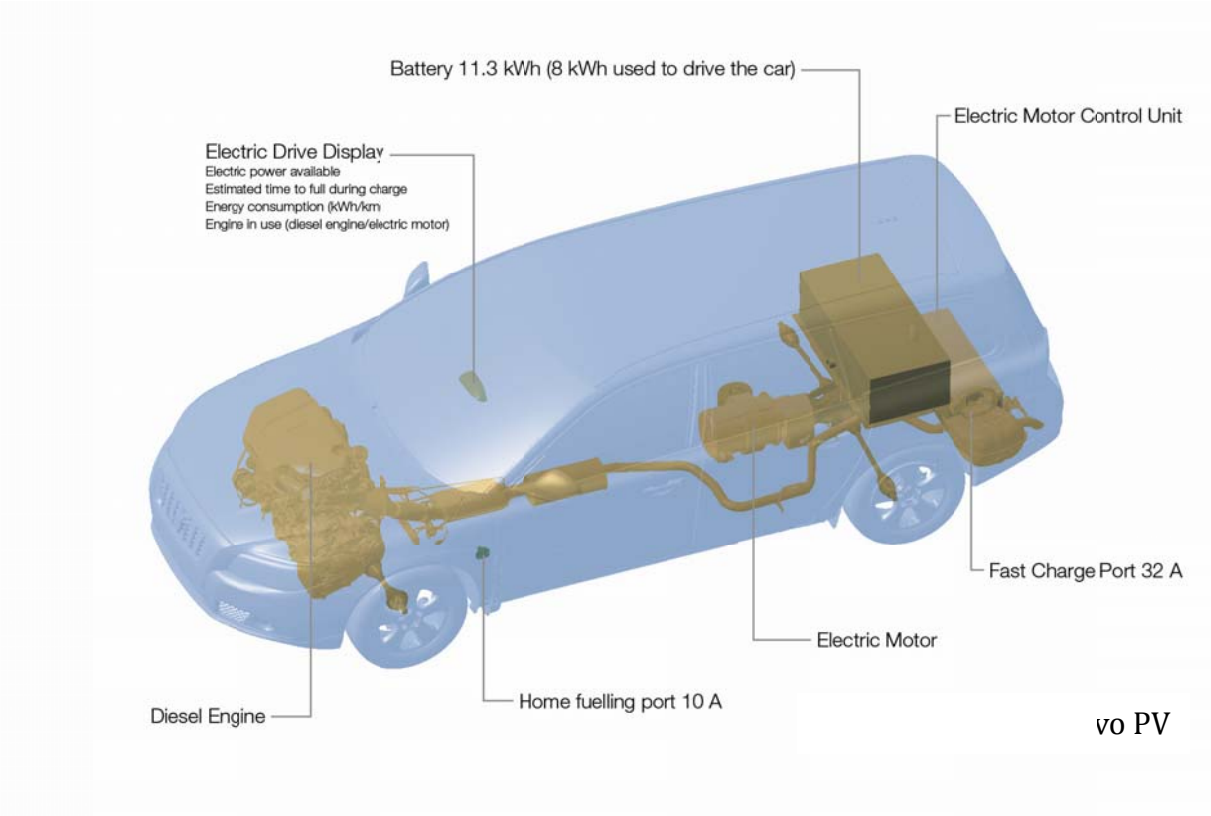
Electric engine between combustion engine and gear box

Source: BMW

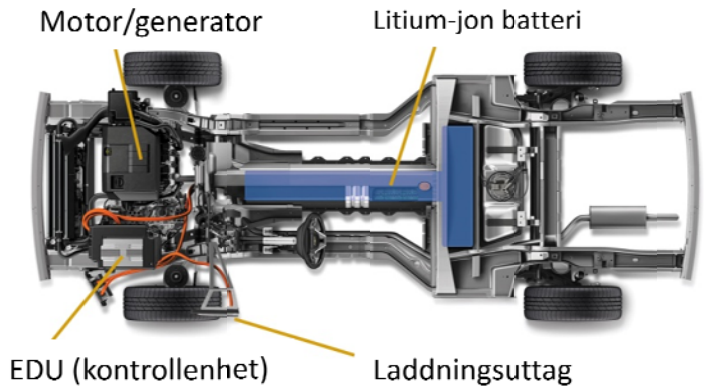


Electric hybrid with possibility to charge at charging station

Can be run by an electric engine and through a gear box with a combustion engine simultaneously


Battery 11.3 kWh (8 kWh used to drive the car)
Electric Motor Control Unit
Electric Drive Display
Electric power available
Estimated time to full during charge
Energy consumption (kWh/km
Engine in use (diesel engine/electric motor)
Fast Charge Port 32 A
Electric Motor
Home fuelling port 10 A
Diesel Engine

vo PV


Motor/generator
Litium-jon batteri
EDU (kontrollenhet)
Laddningsuttag

ine

ole

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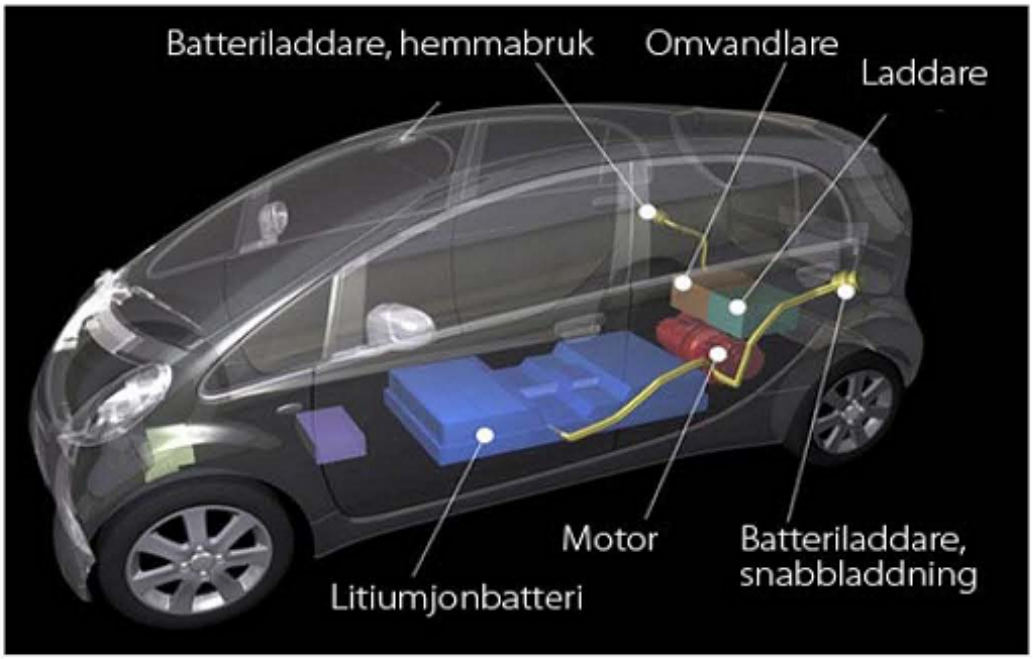
3. Description of different types of electric vehicles and electric hybrids

Examples of general descriptions of available electric vehicles and electric hybrids

Electric car

An electric car is a car without a combustion engine. It is driven only by an electric motor that obtains its high-voltage energy (HV-energy) from, e.g., a battery, which is charged from an electric power outlet.

The figure below shows the electric car's included components; *charger, battery, battery monitoring, motor control, and electric motor*.



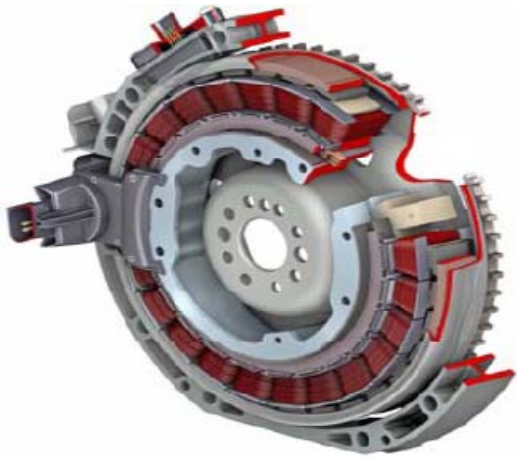
The **charger** is plugged into an electric power outlet and converts the alternating current in the outlet to direct current, which charges the battery. The charger also makes sure that the direct current's voltage suits the battery type, since different battery types have different voltages depending on the vehicle's design. A charger with the wrong voltage may destroy the battery, so the right charger for the right vehicle is important. In electric cars, the charger is often integrated in the car itself and all that can be seen on the outside is a charging outlet for a plug/connector. Sometimes there are two different charging outlets, one for charging in electric power outlets (230V) and one for quick-charging.

The **battery** is the electric car's "fuel tank" where electric energy is stored chemically. There are many different types of batteries, but the original idea is that two substances react with each other and this generate electric energy. In the chapter on batteries there are descriptions of different types of batteries that are common in electric vehicles.

The **battery monitoring system** makes sure that the battery is not overloaded or discharged too much. Different battery types have different sensitivity to over-charging and under-charging, but often over-charging and under-charging reduces battery life. This is avoided with the monitoring system. The system also warns in case of too low charging in the battery and the driver should get to a charging station.

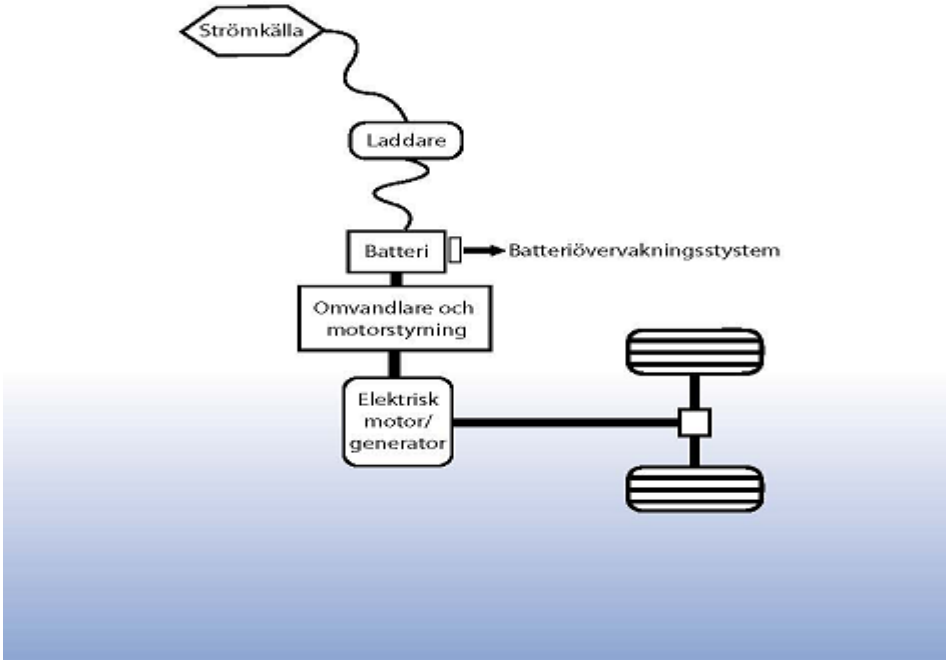
The **motor control** controls the current that runs between the battery and the motor. When the driver presses
on the "accelerator pedal", the motor control supplies the right current to the motor. When the driver lets up the "accelerator" or brakes, then the motor control ensures that the electric motor brakes the vehicle. However, heavy braking requires an ordinary service brake.

The **electric motor** drives the car. There are different types of electric motors that can be used in an
electric car. The different electric motor types have different advantages and disadvantages. For example, they may have different performance, efficiency, and size. All convert the electric energy to kinetic energy that drives the vehicle. The electric motors can also convert kinetic energy to electric energy. An rotating electric motor can generate voltage, often so high voltage that it is dangerous! Most electric cars function as follows; when they are braked by the motor or braked with the brakes, then the electric motor generates electric energy which charges the battery so that the brake energy can be utilised.



Source: Toyota Sweden AB

Electric car



Hybrid car

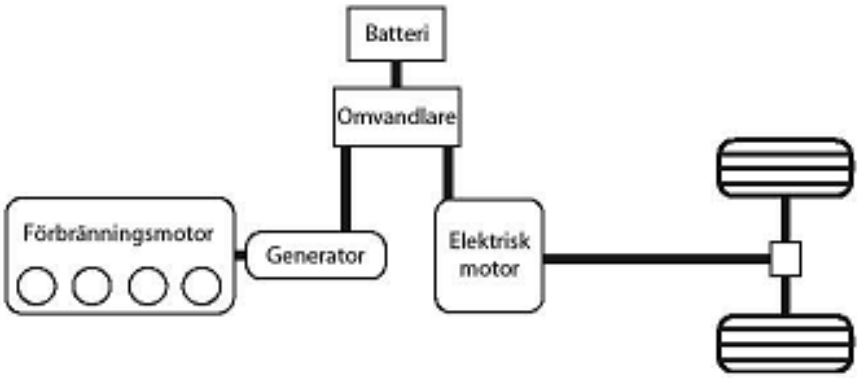
The basic idea in a hybrid system is that a combustion engine (Range Extender) drives an alternator or a fuel cell that charges a battery, which then drives an electric motor connected to the drive axle. There are different types of hybrid cars – for example, series hybrids and parallel hybrids.

In a hybrid car a combustion engine works together with one or several electric motors to give a more fuel-efficient car, among other things. Working together provides the two major advantages, namely that the combustion engine can operate at its most effective rpm and that the energy can be recycled when braking, so called regenerative braking. This reduces fuel consumption.

Hybrid cars always have an electric energy storage, e.g., a battery or super-capacitor, electric motor/electric motors, and electric power converters in between. Just like for electric cars, the hybrid components (electric motors, electric energy storage, and electric power converters) often have much higher voltage than what is present in a conventional vehicle. These higher voltages may, just like ordinary (230 V) wall outlets, be dangerous!

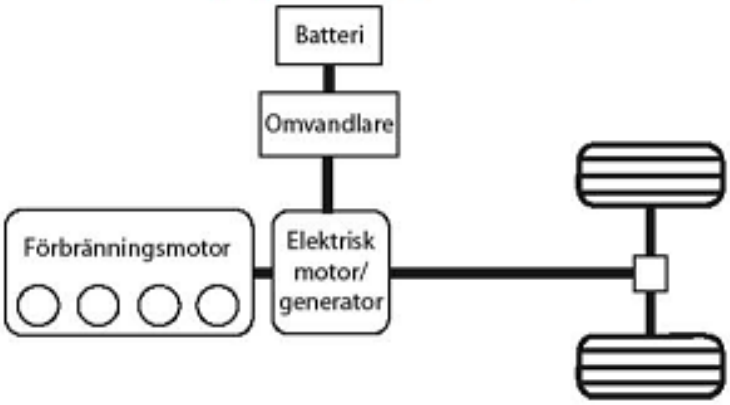
The following describe solutions for hybrid drive:
Series hybrid system
Parallel hybrid system
Series-parallel system
Charge hybrid system
Fuel cell car

Series hybrid system



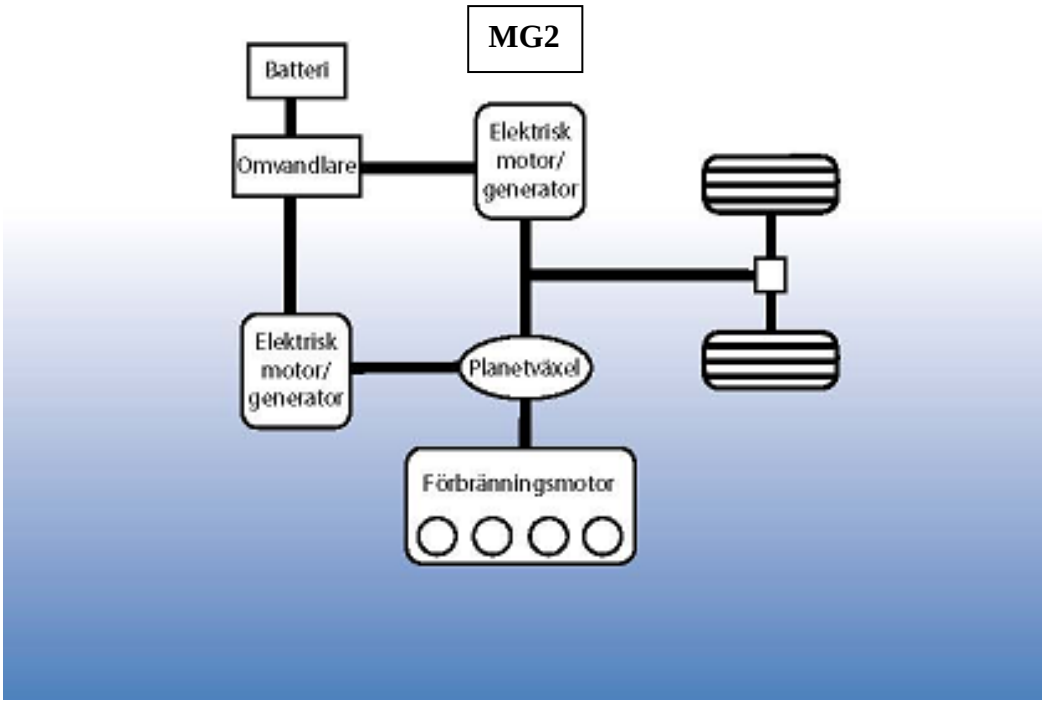
In a series hybrid the combustion engine is connected to an alternator that charges the electric motor's batteries. Then the car is driven by the electric motor. The series hybrid can simply be described as a car that is driven by electric power and that obtains almost all of its electric power from a combustion engine.

Parallel hybrid system



In a parallel hybrid the combustion engine can, by way of the alternator, charge the electric motor's battery and may also be connected to the drive axle via a transmission.
This means that the combustion engine can drive the wheels and, when all energy from the combustion engine is not needed for the wheels, the electric motor can work like an alternator and charge the batteries.
Many parallel hybrids can be run on electric power only, with the combustion engine off.

Series-parallel hybrid

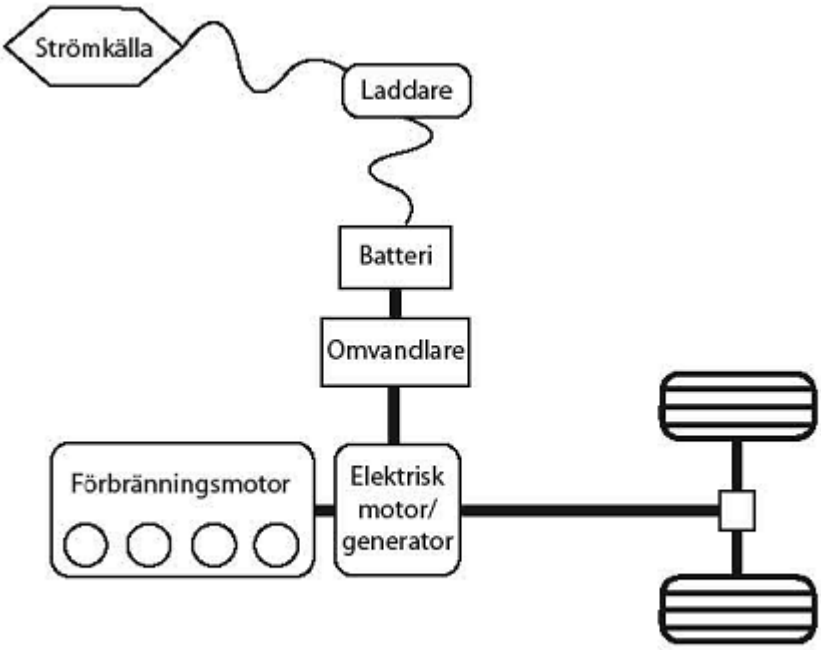


A series-parallel hybrid can both work like a series-connected and a parallel-connected hybrid depending on what is most beneficial at the time. The first electric motor MG1 works like an alternator and uses excess energy from the combustion engine to charge the battery. The second electric motor, MG2, works like a motor and drives the wheels with the energy from the battery. Between the drive and the wheel axle there is a planetary gear, enabling the different combinations of the combustion engine and electric motors.

All hybrid types can charge the batteries when the car brakes. By letting the electric motor work like an alternator, which brakes the car, energy can be recycled and charge the battery. Since the electric motors/alternators MG1 and MG2 are driven by/generate alternating current while the battery handles direct current, there must be a converter between these.

In addition to the hybrid car having both an electric motor and a combustion engine, the difference between an electric car and a hybrid car is that the battery cannot be charged in a power outlet, but only by the car's own combustion engine or braking force.

Charge hybrid car



A charge hybrid car is a hybrid car that also can be charged in an electric power outlet – a combination of a hybrid car and a battery car. Thanks to the electric power outlet, the batteries can be charged without the combustion engine, which means that fuel can be saved. However, there is still a combustion engine in the car and it is started when the battery is discharged and when extra power or range is needed.

Just like a hybrid car, a charge hybrid car can make use of the brake energy when braking.

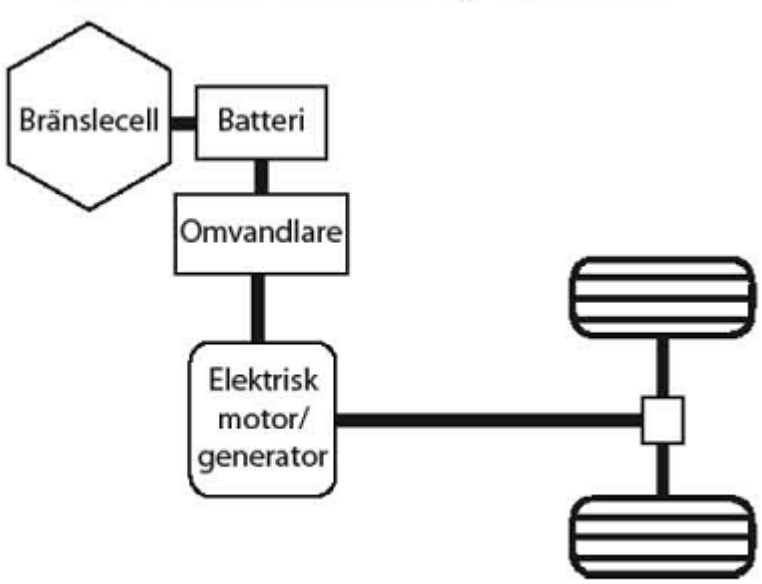
General.

There are many versions, technical solutions, of hybrid vehicles. For example, there are hybrid vehicles that can use several electric motors, gears, and clutches, to function both like a series hybrid and as a parallel hybrid, depending on what is best at the time.

Parallel hybrids may also look different by varying where the electric motor is located in relation to the combustion engine, friction clutches, and transmission. For example, the electric motor can be connected directly to the combustion engine and have a friction clutch to the transmission. But the electric motor may also be connected directly to the transmission, with a friction clutch between the electric motor and combustion engine.

NOTE! Therefore it is always important to have correct knowledge of the vehicle and its systems.

Fuel cell car



A fuel cell car is driven by fuel cells that generate current for an electric motor. The concept is very similar to a hybrid car, with the difference that it is a fuel cell that generates current instead of a combustion engine.

A fuel cell is based on a chemical reaction where hydrogen atoms are divided into protons and electrons at a cathode. To join together again, the protons take a short route through the electrolyte to the anode, while the electrons are forced to take a longer way, and in this way generate current. At the anode, water forms using the hydrogen at the cathode and oxygen at the anode. The choice of electrolyte is important since it must only let through protons and not electrons for the fuel cell to work.
The process itself in the fuel cell does not include any combustion and therefore it produces no other emissions from the vehicle than the water that is formed. Since hydrogen is not available as a pure substance, a fuel cell must also be equipped to separate hydrogen from, e.g., natural gas, methanol, or petrol. Advantages of the fuel cell are that efficiency is quite high, and it does not emit any hazardous emissions.

A fuel cell generates quite low voltage, so to drive a car several fuel cells are required, a so called stack. The cell's working temperature varies depending on the type of material the fuel cell's anode and cathode are made of, and depending on which electrolyte is used.

NOTE! Common for all solutions is that they have components that may contain dangerous voltages!

Voltage and high energy content

Some countries have made principle decisions to use voltages up to 400 volt, but voltages above 650 volt and amperage (current) of more than 300 A may be present in hybrids and electric cars. The cables for these higher voltages and amperages are most often ***orange*** in colour, but also it may be that only the connectors are orange. In general the cables are located in safe structures in the car's designs such as, e.g., the frame tunnel. However, there may be other placement solutions. The different electric and hybrid models may have own individual safety systems that cut off the current in case of, e.g., a collision. This does not mean that the electric energy storage is non-hazardous. If the safety system works and the energy storage is undamaged the high voltage and high energy content is still there, but are now isolated to the energy storage. Often the cars also have a service plug/service breaker/service fuse that is removed before any service work, repairs, or can cut off electric power in case of a collision.

It is important to know that an electric motor in an electric or electric hybrid can generate dangerous voltage when it rotates. In a hybrid car this may be extra important since dangerous voltage can be generated when the combustion engine is running, even if the electric energy storage is disconnected!

NOTE! The safest way to disconnect the voltage is to follow the car manufacturer's instructions.

Keep in mind that it is possible that the car's safety system may be destroyed before it has time to trigger the breakers for main electric power. In case of a severe collision, a possible scenario is that the breakers for main electric power are not turned off and that the collision results in cables outside the battery pack being damaged and coming into contact with some part of the car's chassis. Any personnel, e.g., those repairing damages and Emergency services, should be aware of this risk and proceed with extra caution in these situations.

4. Different types of electric energy storage (batteries, capacitors, etc.)

Lead batteries

Used in forklifts and products requiring lower energy demand.

All 12-volt batteries are lead batteries. However, the power of these is limited and a big battery pack is needed to use these to drive electric and hybrid vehicles. They are not suitable for use in these vehicles due to the lead battery's weight.
The electrolyte is an acid which is highly corrosive.

Nickel-metal hybrid batteries

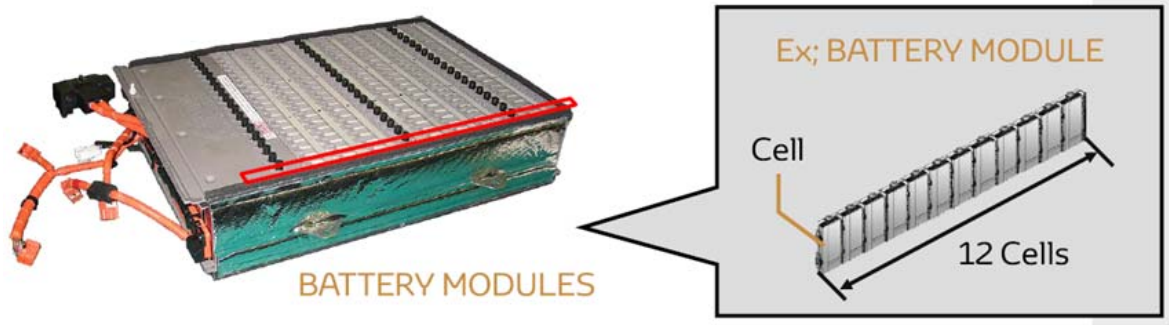
This type has been available since the mid-70s and has been used mainly in today's electric and electric hybrid cars.

The advantage of these batteries is a much better energy density than lead (that is, smaller and lighter but still more energy). As well, these batteries do not contain any environmentally hazardous heavy metals.

Disadvantages are that the batteries have high self-discharge when they are not used, and cooling and monitoring are needed when they are charged since there is a major temperature increase.

Every cell gives 1.2 volt. If a voltage of 400 volt is required, then 320 series-connected cells are needed, where all cells must be good or the capacity of the whole battery drops.
The cathode is made of nickel hydroxide and the anode is a metal hybrid.

The electrolyte is a corrosive alkaline solution where the most important ingredients are potassium hydroxide and sodium hydroxide. The electrolyte is sealed in, which means that only small quantities can leak out in case of, e.g., a collision.



NOTE: DC 201 - 288 V = 1.2 V x X cells x Y modules)

Lithium-ion batteries

There are several hundred types of lithium-ion batteries. The media in the battery may be solid, semi-solid, or liquid, often both fuel and chemically bonded oxygen are found in the media. Chemical reactions may take place in a cell, which means that the cell becomes overheated. This may result in risks of spillover effects and explosions in the whole battery. Battery temperatures above 80° entails danger, at 120° often sees the start of a "run-away" situation. The battery pack is made up of a number of series-connected cells.

Super-capacitors

Super-capacitors absorb and give back brake energy in a superior way compared to batteries. A super-capacitor can store relatively little energy compared to a battery, but it can receive or give off high power for a short time. Therefore the super-capacitor is more suitable in traffic with many starts and stops. Today these are only found in hybrid lorries and buses, as well as in some exclusive sports cars.

NOTE! *The electric energy storages' sealing may not be opened or removed for any reason. This may result in severe or life-threatening electric injuries.*

Fire in battery packs (installed or removed)

The law regarding protection against accidents (2003:778, 2 chap. §2) describes the applicable requirements for fire protection.

Obligations for owners or tenants with user rights to buildings and other facilities
2 § *Owners or tenants with user rights to buildings or other facilities shall to a reasonable extent have equipment for extinguishing fires and for life-saving in case of fire or other accident, as well as otherwise take necessary actions to prevent fire and to prevent or limit damages in case of fire.*

5. Responsibility issues

Responsibility issues link to the National Electrical Safety Board's regulations and general advice (ELSÄK-FS 2006:1) as well as Swedish Standard SS-EN 50110-1, that are applicable when working in electric drive systems.

The company working with vehicles with all-electric or partly electric drive systems, and foremost its appointed persons with relevant training and area of responsibility, always have the responsibility for the work being done in every way according to applicable regulations and their interpretations.

For safest possible handling of electric hybrid and electric vehicles, primarily follow the car manufacturers' manuals and instructions. Use the car manufacturer's special tools if these are required.

Note that, for personal injuries or property damage in connection with an accident where it has its origin in original deficiencies in the vehicle itself (manufacturing defect), the vehicle manufacturer is liable according to the legislation on producer responsibility. The vehicle manufacturer is liable for damages caused by incorrect instructions issued by the vehicle manufacturer or its representative in Sweden

For a company to be permitted to perform work on relevant high-voltage components in drive systems in electric hybrid and electric vehicles, the company must appoint and train personnel according to the car manufacturer's requirements. It may well be of advantage for appointed personnel to attend training in "safe handling of vehicles with high-voltage systems" to obtain knowledge of the area of responsibility and for operations to be performed safely. It should be possible for the person to check and to take action to change that which he/she finds deficient. The employer is obliged to ensure that appointed persons have the right training and knowledge about their work duties, area of responsibility, and their authority. Other jobs that do not concern relevant high-voltage components in drive systems in electric hybrid and electric vehicles may be done by other personnel, with knowledge of the high-voltage systems.

REGULATION (1957:601) on electric high voltage facilities

ELSÄK-FS 2006:1
The National Electrical Safety Board's regulations on general advice regarding electric safety when working in a professional operation

Good electric safety-technical practices
2 § When working where there is electric hazard, safety actions shall be taken according to good electric safety-technical practices, so that assured safety is attained for those participating in the work.
The safety actions shall be based on a risk assessment.

Employer responsibility for working environment.

The employer (MD and/or chairman of the board) has the main responsibility for the working environment.

Under certain conditions allocation of tasks in the work with the working environment may take place. Task allocation is normally placed on persons with a managerial position. This is what is called working environment responsibility or responsibility for occupational safety. There is also responsibility for other actors, manufacturers, suppliers, and others. They are not discussed here (Work Environment Act chap. 3 §5-§14 describes this in detail).

To perform task allocation, some conditions need to be fulfilled, among others;.

- There shall be a need.
- The task allocator shall have competence for the relevant tasks.
- Shall have authority to make decisions and take actions.

- Shall have resources for this in the form of financial means, available personnel, equipment, facilities, time, and knowledge.
- A deputy is appointed in case of longer absence, and the person that has been allocated tasks shall be able to *return* their task allocation when conditions for fulfilling the task do not exist.

Occupational safety responsibility(relevant before something has happened).

If the above conditions are fulfilled then a working environment responsibility (occupational safety responsibility) can be re-allocated or shared by several persons in the organisation. An inspection from the Swedish Work Environment Authority may results in deficiencies being confirmed, which in this case is due to not following laws or regulations. In such a case there is a communication process with possibility for corrective action, but if this does not take place then a violation may result in a *fine,* in certain cases a *sanction fee* (e.g., not inspected pressure vessel), *company fine* or *indemnity* (exception, usually labour market insurances come into force here).

Both the Work Environment Act and regulations contain direct penalty-sanctioning paragraphs and in those cases a task allocation may mean that responsibility is placed at the level where the task allocation has specified this (*issuance of injunction)*. Working environment responsibility may be directed at both physical person and legal person.

A condition for this is negligence, this may be:

- Refraining from due diligence

- Not following provision in law or regulation or from authority
- Not following injunction or prohibition.
- Not following internal instructions, user instructions, normal procedure.
- Not following recognised technical standard.
- Organisational deficiencies, through planning, training, instruction, or supervision.

Criminal responsibility/damage liability (relevant when an accident has occurred).

Criminal responsibility can never be delegated and a court of law appoints the responsibility. Malicious intent or negligence is required for trial. Here the Penal Code sections BrB 3:7,3:8,3:9 are relevant in case of personal injury, there is also BrB 3:10 –*"Neglect the Work Environment Act's requirements on preventing ill health or accidents".* The range of penalties includes means-related unit fine, imprisonment, issuance of injunction, and company fine. Criminal responsibility can only be directed at a physical person.

It is not uncommon that several persons in the organisation are subjected to sanctions, often this is due to an unclear allocation of tasks, out of date, or does not contain all parts in the above statement.

The employer has the main responsibility and shall make sure that each job or action is performed in such a way that the safety requirements for employees are fulfilled (see items below). The employer shall make sure that the employee has documented competence and tools needed to do the work in a professional way and also knows what risks that may be associated with the work. Then the employer delegates tasks under the responsibility for, e.g., disconnecting and marking/placing signs on a car before work (see *Voltage-protected work page 22*).

Electric work responsibility for electric and electric hybrid vehicles

On a work site there shall be a person with electric work responsibility as well as a deputy, when needed, and both shall have documented competence, required resources and authority. The person with electric work responsibility is responsible for actions being taken to obtain satisfactory safety for the company's personnel on the work site. The person with electric work responsibility is the person with the task of being responsible for work with relevant high-voltage components in electric hybrid and electric vehicles being done safely in every way.

The person with electric work responsibility shall:
- be active on the work site
- have proof of competence, knowledge of tasks, obligations and responsibilities
- knowledge of legislation and work environment
- knowledge of risk assessment and valid risk analysis for the vehicle
- accident prevention measures (see Work Environment Act legislation)

6. Competence requirements

A personal proof of competence shall be issued after the person with electric work responsibility has completed training in an approved manner. The length and content of training depends on car brand/car model as well as type of electric and/or electric hybrid vehicle, area of responsibility as well as the company's operation (repair, damage repair, service, or car salvage) and shall be updated as needed.

Job descriptions:

a) The person with electric work responsibility shall have a personal valid proof of competence for each car brand
b) Technicians/mechanics: other work, shall have product and component knowledge of electric and electric hybrid vehicles
c) Other persons shall present diplomas after completing general basic course or equivalent of upper secondary school competence.

The different training shall include the following main areas:

Person with electric work responsibility

a) Proof of competence for car brand
b) Documented product knowledge for specific car models
c) Knowledge of obligations and areas of responsibility.
d) Knowledge of governing legislation
e) Knowledge of electric and hybrid systems
f) Knowledge of different types of hybrid drive
g) Knowledge of safety and risks

Technicians/mechanics

a) General information on electric/electric hybrid vehicles
b) Knowledge of safety and risks
c) Knowledge of components in electric hybrid systems
d) Knowledge of safety and risks
e) What one may or may not do without proof of competence for the high-voltage part.

General basic course

a) Knowledge of different types of hybrid drive
b) Knowledge of safety and risks
c) What one may or may not do without proof of competence for the high-voltage part.

7. Workplace/tools/facilities

Tools, equipment, devices as well as intended workplace shall be used according to the car manufacturer's instructions. If there is a need for insulated tools/equipment, these shall be used. Jobs shall be done in the appointed place.
When work on the HV-system is being done the vehicle shall be marked in a clear and distinct manner so that there is no risk of this going unnoticed by customers or co-workers, e.g., use signs or coloured tape on all of the car's door handles.

NOTE! A vehicle may not be left unattended with accessible live parts/components!

Charging and storing
Handling HV-batteries for charging and storing shall follow the car manufacturer's instructions.

NOTE! HV-batteries shall be stored in dry facilities.

8. Handling of risks

General
The following text is included in ELSÄK-FS 2006:1:

"2 § When working where there is electric hazard, safety actions shall be taken according to good electric safety-technical practices, so that assured safety is attained for those participating in the work. The safety actions shall be based on a risk assessment.

3 § Anyone who uses safety measures that follow standards or good practices other than Swedish standard shall document their risk assessment and issue instructions. Directions shall give instructions to those who shall do the work about the safety actions that must be taken. The same applies if Swedish standard has to be supplemented with regards to the nature of the work".

Work shall always be preceded by taking safety actions according to the car manufacturer's instructions, however, at minimum according to governing industry practices. The principal rule is that work shall be performed with voltage-free HV-system for electric hybrids and electric vehicles' drive systems.

It is important to know that electric components in electric and electric hybrids, such as electric motors, energy storage, and the electric power converters, often have higher voltage than what is present in a conventional vehicle. These higher voltages may, just like ordinary wall outlets, be dangerous. It is important to know that an electric motor in an electric or electric hybrid can generate dangerous voltage when it rotates. In a hybrid car this may be extra important since dangerous voltage can be generated when the combustion engine is running, even if the electric energy storage is disconnected!

NOTE! *If disconnection is not possible, then other safety actions shall be taken when needed by using the protective equipment stated by the car manufacturer, such as insulated tools, etc.*

The risk of contact with electric power (electric power passing through body) is reduced by using personal protective equipment (*see Personal danger page 21).*

Work
Work refers to every form of work with components included in the HV-system.

Electric hazard
That which makes a electric hazard extra dangerous is that it is not visible. Many other hazards can be seen or heard, and thus avoided.

Electric hazard is usually divided into personal danger and fire hazard. In regulations and standards this is stated as protection against electric shock and protection against thermal effects, fire.

Personal danger

Electric power through the body

In case electric power passes through the body, three factors affect the extent of the injuries to the human body. These factors are:

- the amplitude of the amperage (current)

- the electric power's path through the body

- the time that the electric power passes through the body

The amplitude of the amperage (current) depends on factors such as voltage level and resistance in the body. Measurements reported in IEC 479-2 show that the human body's impedance (with phase voltage) varies between 990 Ω and 2,085 Ω.

According to proposals in ECE R 100, the limits for dangerous voltage are 30 V AC and 60 V DC (certain car manufacturers state limit values for alternating current 25 V AC and for direct current 60 V DC).

For current to pass through the body during work in an electric or hybrid vehicle, the body shall simultaneously come into contact with the voltage source's both terminals. The voltage levels are usually significantly higher than in a normal electric power outlet, and since there is no protection in the form of a ground-fault interrupter in vehicles, the risk of injury in case of electric power passing through the body is significantly higher.

Use personal protective equipment to reduce the risk of electric power passing through the body.

NOTE! *The industry recommends that persons undergo approved CPR-training and that a defibrillator/heart starter is available in every workplace.*

Protection against thermal effects, fire

Electric arc

An electric arc results at short-circuiting of voltage sources with high energy content, e.g., a car battery. A 12-volt car battery produces a significant electric arc in case of short-circuiting between the terminals. Batteries for drive systems for electric and hybrid vehicles have a significantly higher energy content and thus short-circuiting may have severe consequences.

According to physicists, an electric arc is a conducting mass of gas. When the air between the live parts exceeds 3,000 degrees Celsius, the air loses its electric insulation capacity and the electric arc lights up. The electric arc generates very high energy in the form of heat and light. A quick pressure-increase results and hot gases are formed. The heat in the middle of the electric arc may be 3,000 - 6,000 degrees Celsius, which means that steel and copper not only melt, the materials actually gasify.

The high temperature may cause severe burn injuries and there is also risk of combustible materials nearby catching on fire.

NOTE! *Keep in mind the fuel with which the hybrid vehicle has been filled.*

To avoid electric arcs, the vehicle must always be without voltage according to the manufacturer's instructions before starting to work.

Risk assessment

Assessment that is the basis for planning safety actions (see checklist appendix 1).

Electric safety planning; safe disconnection, voltage-protected work

Person with electric work responsibility shall always, before starting work, perform electric safety planning according to the car manufacturer's instructions as well as governing regulations and requirements. This includes ensuring that only an authorized person will do the work, having correct technical information available for the relevant vehicle, having taken safety actions to reduce risks; performing check for no voltage (no electric power) to ensure that the drive system is disconnected (powerless). Then the vehicle shall be marked with, e.g., signs or in some other way to show that the drive system is not live. Also, the person with electric work responsibility shall make sure that there is no risk that the vehicle's electrical system accidentally can become live or be connected to a live mains network during the work by others than the authorized person.

NOTE! The HV-system may be supplied with voltage for up to 10 minutes after being turned off (see car manufacturer's instructions).

Voltage-protected work means that a technician at no time risks that a body part, non-insulated implement or tools can come into contact with dangerous voltage. This can be done by, e.g., an authorised person making sure that the vehicle is without voltage supply and marks/indicates this in a clear and safe way (see above under "Person responsible for electric work"), and during the work uses the protective equipment prescribed by the car manufacturer. After work is finished, the same person checks that all systems are connected correctly and then connects the vehicle to the voltage supply.

Finishing the work

After finishing the work the person responsible for electric work shall make sure that the vehicle is supplied with voltage and that all safety measures, guards, and blocking are removed. Also, make sure that parts/components, such as replaced batteries, are stored or charged in the intended place. Final check of the vehicle is performed according to the car manufacturer's instructions, ensuring that the vehicle after the work fulfils the standard and safety intended by the car manufacturer.

9. Points to keep in mind

1. Person responsible for electric work has responsibility for the work
2. Perform risk assessment on work site
3. Perform risk analysis where there is a risk of electric hazards, e.g., for every car model
4. Use the intended workplace
5. Voltage shall be disconnected
6. The vehicle shall be marked as being without voltage (powerless) after check
7. The HV-system may be supplied with voltage for up to 10 minutes after being turned off (see car manufacturer's instructions)
8. Do not expose certain types of batteries (see earlier heading 4 page 13) to temperatures above 80° degrees since this may be dangerous.
9. After finished work and final check, turn on voltage supply to the vehicle
10. Remove the marking that the vehicle is without voltage (powerless)
11. Check all relevant vehicle functions

10. Laws/regulations and terminology

Legislation

The following legislation, standards, and manuals describe safe handling of vehicles with all-electric or partly electric drive systems

- National Electrical Safety Board's regulations and general advice (ELSÄK 1999:5) for definitions and explanations of terms
- National Electrical Safety Board's regulations (ELSÄK-FS 2006:1) and general advice on electric safety when working in a professional operation.
- Applicable parts of Swedish Standard (SS EN 50 110-1) for care of electric facilities.
- Swedish Work Environment Authority's regulations (AFS 2006:4) on use of work equipment.
- Swedish Work Environment Authority's regulations (AFS 2001:1) on systematic work with work environment issues and general advice on applying the regulations
- Work Environment Act (SFS 1977:1160) 3 chap. 2 § informs of the employer's main responsibility for the work environment
- Rules for approving (ECE R 100) electric cars with regards to design and safety
- The law regarding protection against accidents (2003:778) 2 chap. 2 § describes applicable requirements for fire protection.

Terminology

Person with electric work responsibility, electric and electric hybrid vehicles = person with documented competence whose task is to be responsible for performing the electric work, as well as be responsible for taking safety actions in connection with electric work.

Electric energy storage = storage of electric energy, e.g., in batteries, capacitors, etc.

HV-voltage = High-voltage not exceeding 1,000 V AC or 1,500 V DC

HV-system= System for high-voltage

Proof of competence = A personal document or certificate confirming a person's knowledge.

11. Source reference

(1) What is an electric car? - a crash-course in the unknown world of the electric car
Greta Björling, Gustav Degerman
Project in environment-adapted design
KTH
May 2010

(2) Other figures according to source reference

Appendix 1: Tools for person with electric work responsibility

NOTE! This must be performed where there is a risk of electric hazard (e.g., for every new car model)

	yes	no	not applicable
Risk analysis before work			
1. Manufacturer's instructions available for the relevant vehicle?	☐	☐	☐
2. Can the vehicle's HV-drive system be fully disconnected?	☐	☐	☐
If answer to question is 'yes'			
a) is protective equipment available according to instructions?	☐	☐	☐
b) is intended workplace available?			
c) are there insulated tools and equipment?	☐	☐	☐
If answer to question is *'no'* the situation shall be assess by person with electric work responsibility for electric and electric hybrids.			
3. Are correct tools and equipment available?	☐	☐	☐
4. Personnel about to do the work has the correct competence?			
a) Person with electric work responsibility with proof of competence/certificate	☐	☐	☐
b) knowledge of safety requirements and rules	☐	☐	☐
5. Is the vehicle marked according to requirements?	☐	☐	☐
6. Have risk assessment and risk analysis been performed?	☐	☐	☐

Actions after finishing the work			
1. Are all jobs finished and all involved informed?	☐	☐	☐
2. Are temporary safety measures removed?	☐	☐	☐
3. Is the vehicle's HV-drive system restored?	☐	☐	☐
4. Have batteries or other materials that may contain dangerous charges been taken care of according to the manufacturer's instructions?	☐	☐	☐

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