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Plug-in Hybrid infrastructure and Porsche Car Connect

## **Intelligent tour de force: electrical and electronic systems**

Advanced development of the Panamera S E-Hybrid into a plug-in hybrid has significantly extended the range of possibilities for electric mobility. The ability to charge the car from the electrical grid permitted the use of a battery with over five times the energy capacity of the one in the previous model. This battery can also handle the higher power levels of the new electric motor, whose peak power has doubled compared to the previous model. At the same time, entirely new convenience features were implemented, some of which can be activated and accessed via a smartphone app. This required wide-ranging new development of the infrastructure and its control – from the charger to peripheral equipment for the new battery concept as well as high-voltage management and the improved power output of the electric motor. Consequently, one of the most challenging core tasks in the process of creating the new Panamera S E-Hybrid was to develop electrical and electronic structures that could handle these higher electrical power levels and extended functionalities.

The core element of the new hybrid drive is the battery whose package design and management were developed in-house at Porsche. All other components rely on its performance. Porsche is implementing a newly developed high-voltage battery based on lithium-ion technology, which is integrated in a space-saving location beneath the boot floor. This is the same mounting space that was used for the nickel metal hydride battery of the previous model. The primary advantage of lithium-ion technology is its high energy density of 70 watt-hours per kilogram. But its power density is also high at 896 watts per kilogram, which enables a high level of electrical performance.

The high-voltage battery consists of 104 prismatic cells, distributed among eight modules of 13 cells each, and it has a nominal voltage of 384 Volts. It has a nominal energy capacity of 9.4 kilowatt-hours, of which 7.5 kilowatt-hours are used for the drive system. The new battery is designed so that it can output a maximum power of 120 kilowatts for a period of ten seconds – significantly more power than the electric motor consumes at its peak power.

The battery is surrounded by a cooling jacket and is coupled to the air conditioning loop via a dedicated evaporator. The refrigerant flow is routed through the battery pack by a system of lines; this effectively removes excess heat to keep the cells within the ideal temperature range of 20 to 44 degrees Celsius. A separate auxiliary electric heater was installed as well to operate the battery in winter temperatures. The battery is maintenance-free, and there are no wear parts.

### **Universal plug-in charge system: all charger types as standard**

Porsche has developed an entirely new plug-in charging system to supply energy to the battery. A Porsche Universal Charger (AC) by Porsche Design is supplied as standard with every Panamera S E-Hybrid. It is used to connect the vehicle to the electrical grid. This charger comes with two standard supply cables: one for household electrical outlets, and the other for connecting to industrial or heavy-current electrical outlets. The customer can easily connect the supply cable that is appropriate for the available connection.

The lithium-ion battery is charged via the vehicle charge port located on the vehicle's rear side panel, on the side opposite the conventional fuel door. Two integrated LED charging indicators inform the user of the charge status (LED on right) and connection status (LED on left). The two LED lights are located near the plug connection. If the right LED lights a constant green, this indicates a fully charged battery, while quick pulsing of the light indicates an active charging process. The slower the LED pulses, the higher the battery charge state. This gives the driver quick feedback on the battery charge state. The charging time is primarily determined by the power handling ability of the on-board charger. In the charger, the AC current from the infrastructure is converted to DC current that can then be stored in the high-voltage battery.

The charging power in the Panamera S E-Hybrid is 3.6 kW, and the compact on-board charger is installed in a space-saving location in the right side wall of the boot. The Panamera S E-Hybrid can be fully charged in just around two and a half hours (at 16 Amperes) or in less than four hours (at ten Amperes), depending on the electrical connection.

**Power electronics control energy flow like in a single-family home**

The energy output from the battery to the electric motor is handled via the power electronics. It consists of a pulse controlled inverter and a DC converter (DC/DC). The inverter converts the 384 Volt DC voltage of the high-voltage battery into three-phase AC current with variable amplitude and frequency for the electric motor. When the motor is operated as a generator in a recuperation phase, the sequence is reversed. The DC converter is used to supply the 14-Volt vehicle electrical system with energy from the high-voltage network.

The pulse controlled inverter, charging cable and Hybrid Manager unit that is mounted on the electric motor must handle very high electrical currents. The voltages at the electric drive unit are between 280 Volts and 430 Volts and currents are up to 450 Amperes. That is significantly more than the entire power supply for a single-family home. The power electronics controls the synchronous motor by a pulse-width pattern. Its drive control is based on the field-oriented control principle. In what is known as an armature adjustment range, the motor can be controlled up to around 2,200 rpm via the voltage in the armature. Then the electric motor is driven with field-shunting control, i.e. by reducing the excitation flow.

As in the previous model of the new Panamera S E-Hybrid, the brake system recovers braking energy that would otherwise be lost and feeds it into the high-voltage battery (electrical system recuperation). In this system, the brake unit is designed such that in all positions within tolerance limits, recuperation is regulated up to the maximum before the hydraulic braking action begins. Compared to the previous model, this characteristic map was adapted to the more powerful electric motor and further optimised for driveability and pedal feel.

This means that at speeds under approximately 40 km/h the braking energy is practically fully recoverable and can be stored in the form of electrical energy.

**Unique convenience: remote control by smartphone and auxiliary climate control**

The new conceptual approach for the electronic infrastructure includes driver information systems with extended functionality for the plug-in hybrid. This has resulted in hybrid-specific indicators in the instrument cluster and the optional Porsche Communication Management (PCM) unit. In the new plug-in hybrid, Porsche is also introducing convenient remote control of the vehicle via a smartphone app under the name Porsche Car Connect. The app is organised into three categories: e-mobility with hybrid-specific contents, Remote for general functions, which are also available as an option in other Porsche vehicles, and the Vehicle Tracking System (VTS), which is also available for conventional vehicles.

The networking of vehicle and driver via smartphone plays an important role in the Panamera S E-Hybrid, because it makes special functions such as external charging of the high-voltage battery more transparent. The driver can access and control key vehicle information via the smartphone app. e-mobility functions are subdivided into four menu areas: charging status overview, driving range management, charging timer and optional remote control of the auxiliary climate control system. In addition to the battery charging status and remaining charging time, momentary driving ranges are shown for electric driving and combustion engine driving. Here, the electric driving range is intuitively visualised on a navigation map. Three different departure times can be selected in the Charging Timer function. The system controls the charging process based on these settings to charge the battery as protectively and cost-optimally as possible.

Electrification of the climate control system fulfils the prerequisite for another very convenient option in the plug-in hybrid, which is auxiliary climate control. Via the Charging Timer, the climate control system can be activated so that the interior reaches the prescribed temperature by the specified departure time. The vehicle interior is heated or cooled accordingly. In the winter, heating power is also generated electrically by a high-voltage auxiliary heater.

Auxiliary climate control is possible – either with the charging cable connected or powered directly by the on-board battery. Preheating at low outside temperatures also increases electric driving range, since it eliminates the cold start and its associated higher energy demand.

**Porsche Car Connect is based on dedicated architecture**

Porsche Car Connect supplements the existing Online Services that Porsche currently offers to its customers. The new vehicle-related service is built on a dedicated architecture, in which the vehicle is networked to a server via an internal communication unit and the mobile phone network. The driver communicates with the vehicle via a smartphone app – and this communication always occurs via the server that provides certain functions and also acts as a memory buffer.

Porsche Car Connect is also offered as an option in other non-hybrid Panamera models, naturally without e-mobility functions. Porsche Car Connect is a standard feature of the Panamera S E-Hybrid, and the related e-mobility services are provided free-of-charge for a period of five years. Porsche provides the Remote and Vehicle Tracking System services to buyers of the Panamera S E-Hybrid free-of-charge for six months. Porsche Car Connect is offered together with Online Services in the USA, South Africa and in most European countries. Exceptions are Croatia, Bosnia, Albania and Russia and the Ukraine, where only the vehicle-based Porsche Car Connect can be ordered. Only Online Services are being offered so far in Australia, New Zealand, Canada, San Marino, Vatican City, Andorra, Gibraltar, Liechtenstein and Monaco.