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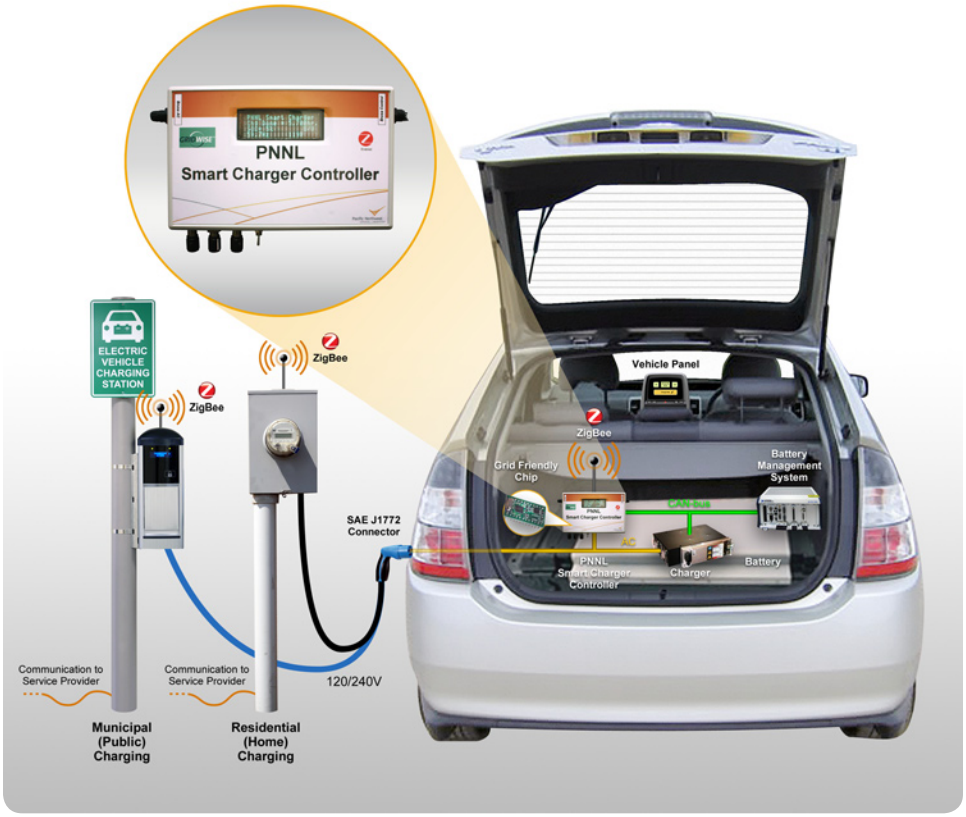
PNNL Smart Charger Controller

The Smart Charger Controller optimizes the charging schedule in a Plug-In Hybrid Electric Vehicle (PHEV) to minimize cost, enhance grid stability, and to safely set the maximum battery charge rate within the electrical limits of the battery, battery charger, and premises/charging station.

Smart Charger Controller

Developed at the U.S. Department of Energy's Pacific Northwest National Laboratory, the device is one of four major components in a PHEV's battery charging system; the other components include the battery charger, the battery management system, and the operator control/preference selection module.



Smart Charger Configuration

COMMUNICATION

The Smart Charger Controller communicates with the battery charger, charging station/premises, display, and the battery management system to set and control when and how the vehicle's battery will be charged.

i. The Smart Charger Controller currently implements all communications through RS-232, SPI, I_2C, ZigBee®, and CAN 2.0 methods.

ii. The J-1772 standard assigns connector pins for vehicle to charging station/premises communication. The Smart Charger Controller design incorporates the capability to communicate using this capability.

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iii. The communication interfaces include:
   1. ***Premises/Charging Station:*** *currently ZigBee and RS-232. Capability available for USB, Ethernet, and 802.11. Communicates electrical capabilities, price schedules, vehicle ID/payment authorization.*
   2. ***Battery Charger:*** *currently CAN-bus. Capability available for USB, RS-232, RS-485, Ethernet, 802.11, and PWM. Communicates the battery charger status, battery status, and allowable charge rate information.*
   3. ***Battery Management System:*** *currently CAN-bus. Capability available for USB, RS-232, RS-485, Ethernet, and 802.11. Communicates charging related information appropriate to the installed battery type.*
   4) ***Grid Friendly™ Module and External Memory:*** *I_2C or SPI. Internal communication only.*
   5) ***Display/Operator Interface:*** *I_2C, SPI, RS-485, CAN, ZigBee. Communicates owner preferences, vehicle ID/payment authorization, etc.*

FUNCTIONALITY

The Smart Charger Controller's primary functions are to optimize the charging schedule for minimum cost and enhance grid stability.

i. Five charging methods are incorporated into the Smart Charger Controller.
   1. ***Price-Based Charging Strategy:*** *optimal-cost start/stop times for charging based on time of use, critical peak pricing, and real-time pricing*
   2. ***Grid Services:*** *utility directed reduction or increase in allowable charge rates.*
   3. ***Regulation Services:*** *a PNNL real-time technology that detects grid stress by monitoring AC frequency and AC voltage and adjusts charging rate.*
   4. ***Grid Events:*** *a PNNL real-time technology that allows the charging process to stop if a "grid event" occurs.*
   5. ***Charge Now:*** *overrides all other charging methods.*
   6. ***Easy extendibility*** *of optimal charging strategies to other features such as vehicle preheating and battery preference.*

ii. Optimization process completed within 100 milliseconds of price or method change.

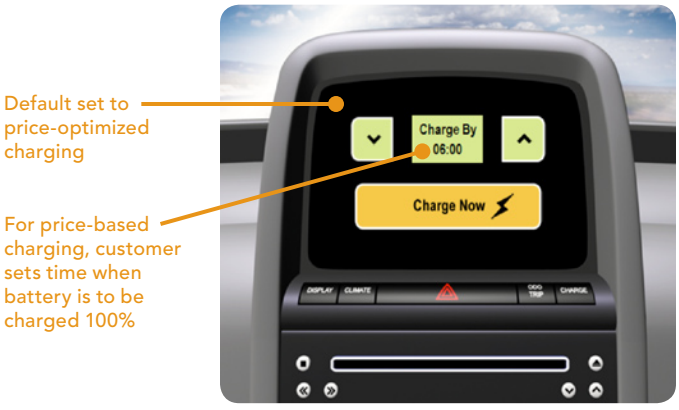
iii. Memory
   1. ***Charging History Table:*** *a record of charging related events including charge start/stop times, grid events, optimization method, etc.*
   2. ***Expandable storage location*** *for VIN/PIN/ encryption keys, etc.*
   3. ***Retain prior owner preferences*** *(i.e. charge completion time, charging method, etc.)*

iv. Maintain the battery charge rate within the electrical limits of the battery, battery charger, and premises/charging station. With battery status information available (i.e. battery temperature, pressure, cell voltage), the battery charge rate limit, state-of-charge, state-of-health, etc. could be determined.

v. The vehicle owner retains overall control:
   1. *Option for "**owner override**" of the Smart Charger Controller to charge the battery now.*
   2. ***Owner preferences*** *usually considered higher priority (e.g., desired charge end time) than grid information. The exception is grid events.*
   3. ***Owner selects*** *one or several cost minimization methods to operate concurrently.*
   4. ***Owner determines*** *completion time for vehicle charging.*

CONCEPTUAL IN-VEHICLE CONTROL PANEL

The conceptual in-vehicle control panel allows the vehicle operator to adjust and initiate the Charge Completion time within the vehicle, or override the optimized process and "Charge Now." When either of these options are selected by the vehicle operator, the first step in the charging process is to verify vehicle registration at the charging station or premises.

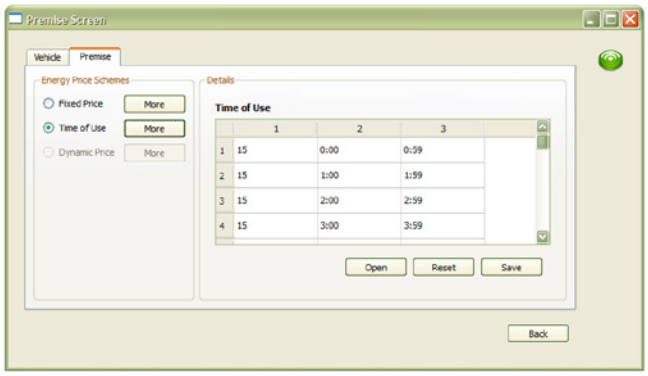


Smart Charger Vehicle Panel

CONCEPTUAL CHARGING STATION CONTROL PANEL

The conceptual premises/charging station panel is the Operator Interface and external communication's entry point to the Smart Charger Controller. This display provides a local indication of the Smart Charger Controller, battery charge status, and is the credit/debit card entry point for payment of services. It also acts as the communications bridge between the vehicle and the utility. The communications between the premises panel and the Smart Charger Controller includes:

i. Current date and time
ii. Charge complete data and time
iii. Charge method
iv. Premises/Charging Station voltage, current, and power limitations
v. Owner preferences
vi. Utility pricing schedule
vii. Registration information
viii. Demand response signals

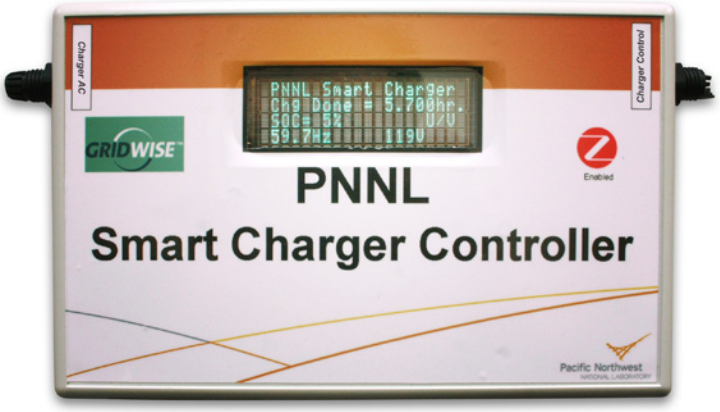


Smart Charger Premises Screen

DEVICE INTERFACE

The Smart Charger Controller requires two external cables to implement its features. These cables enter the box near the "Charger AC" and "Charger Control" labels.

i. Charger AC connection provides the Grid Friendly Module with a signal proportional to the main's voltage.
ii. Charger Control connector carries the CAN-bus signals from the Smart Charger Controller to the battery management system and the battery charger. Two pins are used for ground and one pin is the 9-30VDC supply to the Smart Charger Controller.



Smart Charger Controller

PHYSICAL SPECIFICATIONS OF THE SMART CHARGER CONTROLLER

i. DC input voltage: 9-30VDC
ii. DC input current (operating): 300mA
iii. Size: 8-1/2" x 5-1/2" x 1-1/2"
iv. Weight: 21oz.

For more information about the PNNL Smart Charger Controller, contact:

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