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(54) **REGISTRATION-BASED VEHICLE BATTERY CHARGING SYSTEM**

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G06F 9/44 (2006.01)

(52) **U.S. Cl.** **701/22**; 717/166

(58) **Field of Classification Search** ..... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,327,227 B2 2/2008 Ohtaki et al.
7,402,978 B2 * 7/2008 Pryor 320/104
(Continued)

FOREIGN PATENT DOCUMENTS

CN 1723142 1/2006
JP 2003-023378 1/2003
(Continued)

OTHER PUBLICATIONS

Office Action (and English translation), dated Apr. 20, 2011, issued in corresponding Chinese Application No. 2007800280509.

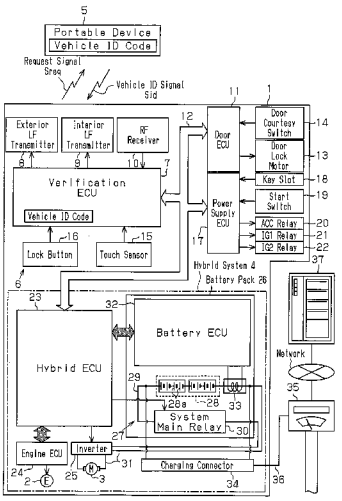
(Continued)

Primary Examiner — Thomas Tarcza
Assistant Examiner — Nagi Murshed
(74) *Attorney, Agent, or Firm* — Saul Ewing LLP

(57) **ABSTRACT**

A charging system that facilitates tracking of a stolen charging subject. The charging subject includes a battery and has a unique identification code. A charging device is connected to the battery of the charging subject by an electric cable, and the battery is chargeable. A server is connected to either one of the charging device and the charging subject and manages charging of the charging subject with the charging device. The server is cable of registering an identification code of the charging subject. The server obtains the identification code from the charging subject, determined whether or not the obtained identification code is registered in the server, and transmits to the charging device a charging prohibition command for prohibiting charging of the charging subject with the charging device when the obtained identification code is not registered in the server.

16 Claims, 6 Drawing Sheets



U.S. PATENT DOCUMENTS

2003/0105662	A1*	6/2003	Koketsu et al.	705/13
2004/0225419	A1*	11/2004	Sakai et al.	701/1
2005/0016781	A1*	1/2005	Muta	180/65.2
2005/0044245	A1	2/2005	Hoshina	
2006/0130033	A1*	6/2006	Stoffels et al.	717/166
2006/0175103	A1*	8/2006	Iida et al.	180/65.4
2006/0233545	A1*	10/2006	Senba et al.	396/529
2007/0080827	A1*	4/2007	Huang	340/945
2007/0126395	A1*	6/2007	Suchar	320/109
2008/0042810	A1*	2/2008	Nakane et al.	340/426.18
2009/0192655	A1*	7/2009	Ichikawa et al.	700/291
2009/0287499	A1*	11/2009	Link, II	705/1

FOREIGN PATENT DOCUMENTS

JP	2003-048513	2/2003
JP	2004-284506	10/2004
JP	2004-287720	10/2004
JP	2005-115667	4/2005
JP	2006-006039	1/2006

OTHER PUBLICATIONS

Form PCT/IB/338 and English translation of the International Preliminary Report on Patentability, dated Feb. 19, 2009, issued in priority International Application No. PCT/JP2007/063859.

International Search Report, dated Sep. 25, 2007, issued in priority International Application No. PCT/JP2007/063859.

* cited by examiner

Fig.1

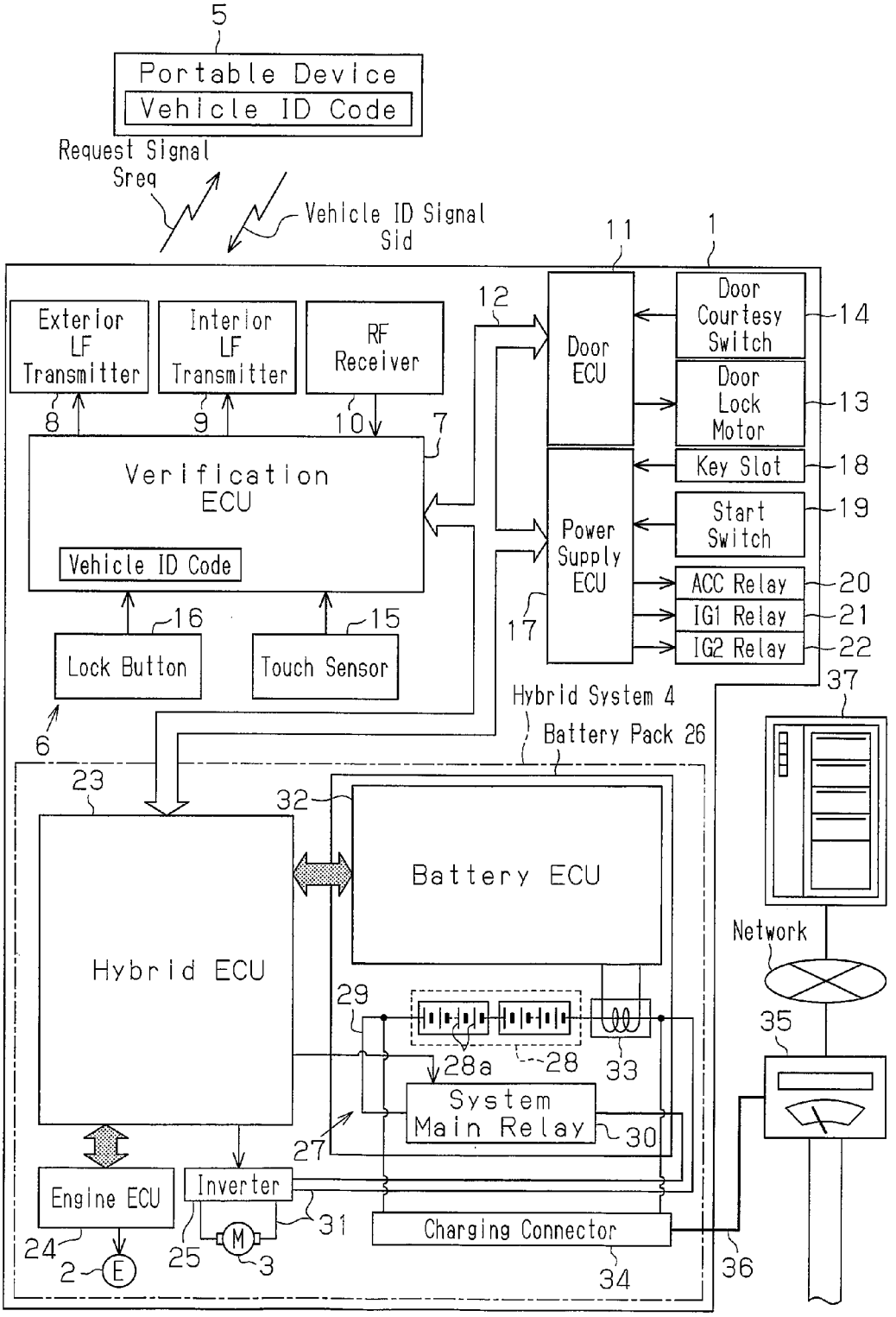
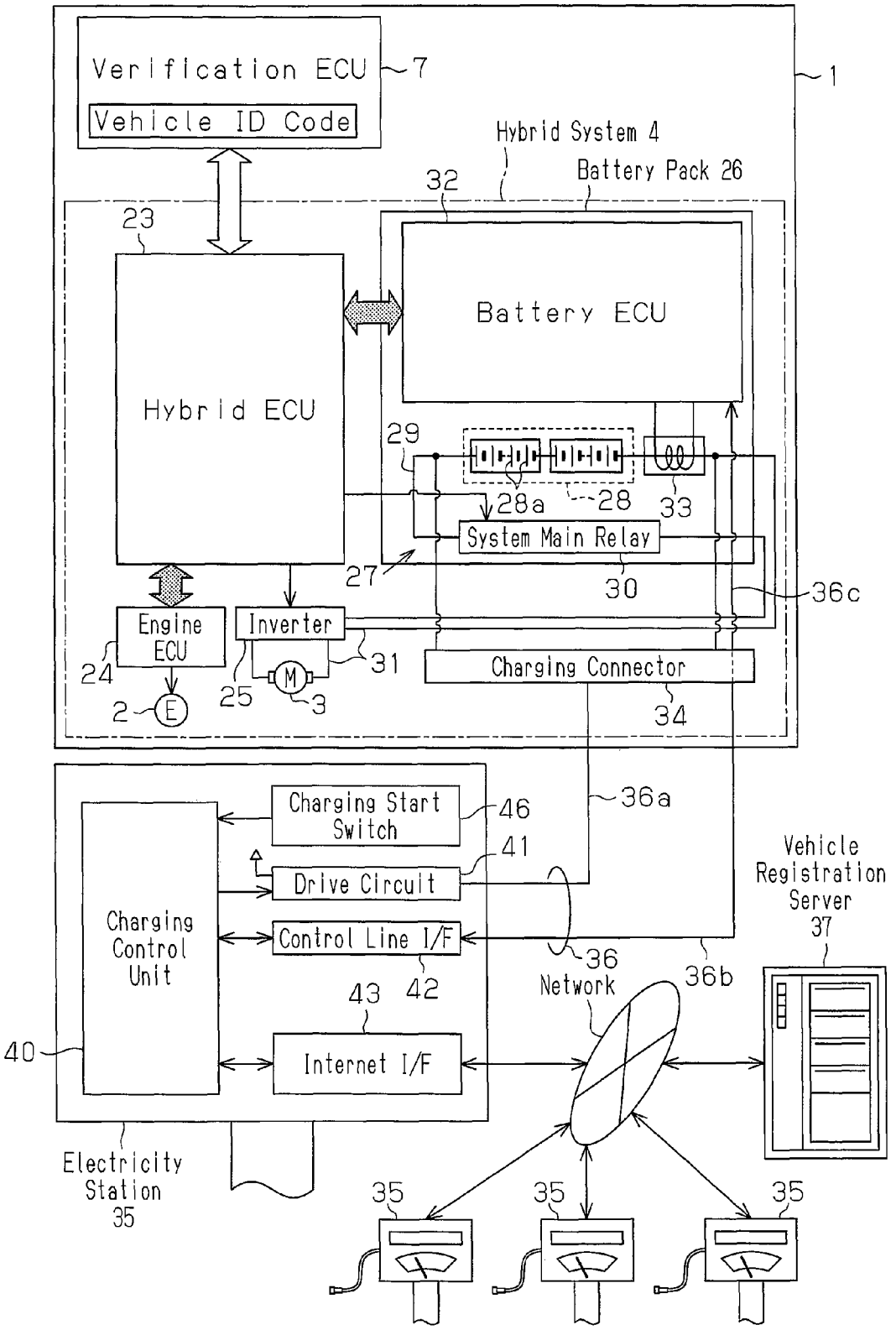

5
Portable Device
Vehicle ID Code
Request Signal
Sreq
Vehicle ID Signal
Sid
11
1
12
Exterior LF Transmitter
Interior LF Transmitter
RF Receiver
Door ECU
Door Courtesy Switch
Door Lock Motor
Key Slot
Start Switch
Power Supply ECU
ACC Relay
IG1 Relay
IG2 Relay
8
9
10
7
Verification ECU
Vehicle ID Code
16
15
Lock Button
Touch Sensor
6
17
14
13
18
19
20
21
22
37
Hybrid System 4
Battery Pack 26
23
32
Battery ECU
Hybrid ECU
Network
29
28a
28
33
35
System Main Relay
30
27
Engine ECU
Inverter
31
Charging Connector
24
2
25
3
34
36

Fig.2


Verification ECU
Vehicle ID Code
7
1
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Battery Pack 26
32
23
Battery ECU
Hybrid ECU
29
28a
28
33
System Main Relay
27
30
36c
Engine ECU
Inverter
24
31
Charging Connector
25
M
3
2
E
34
36a
Charging Start Switch
46
41
Drive Circuit
Vehicle Registration Server 37
Charging Control Unit
Control Line I/F
36
Network
36b
43
42
40
Internet I/F
Electricity Station 35
35
35
35

Fig.3

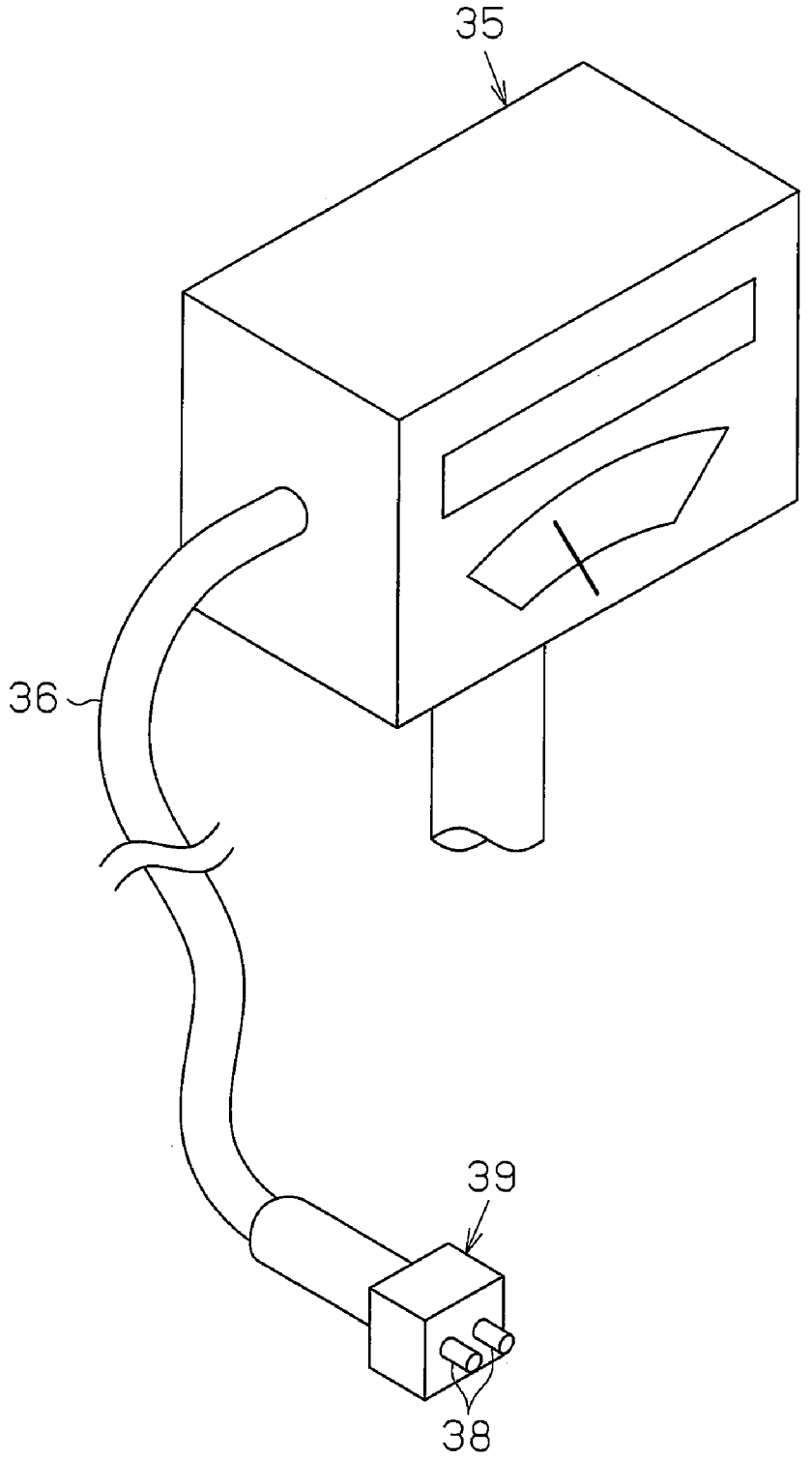


Fig.4

44 Memory

45 Registered Vehicle File

45a Vehicle ID Code	45b Details	45c Stolen Vehicle Registration
12345678-9	Name, Address, Telephone No., etc.	No
•••••••••••	••••••••••••••	•••
•••••••••••	••••••••••••••	Yes
•••••••••••		•••
⋮	⋮	⋮

Fig.5

44 Memory

Charging History

Vehicle ID Code	Charging Date and Time	Electricity Station Location
•••••••••••	••••••	•••••••••••
•••••••••••	••••••	•••••••••••
•••••••••••	••••••	•••••••••••
•••••••••••	••••••	•••••••••••
⋮	⋮	⋮

Fig.6

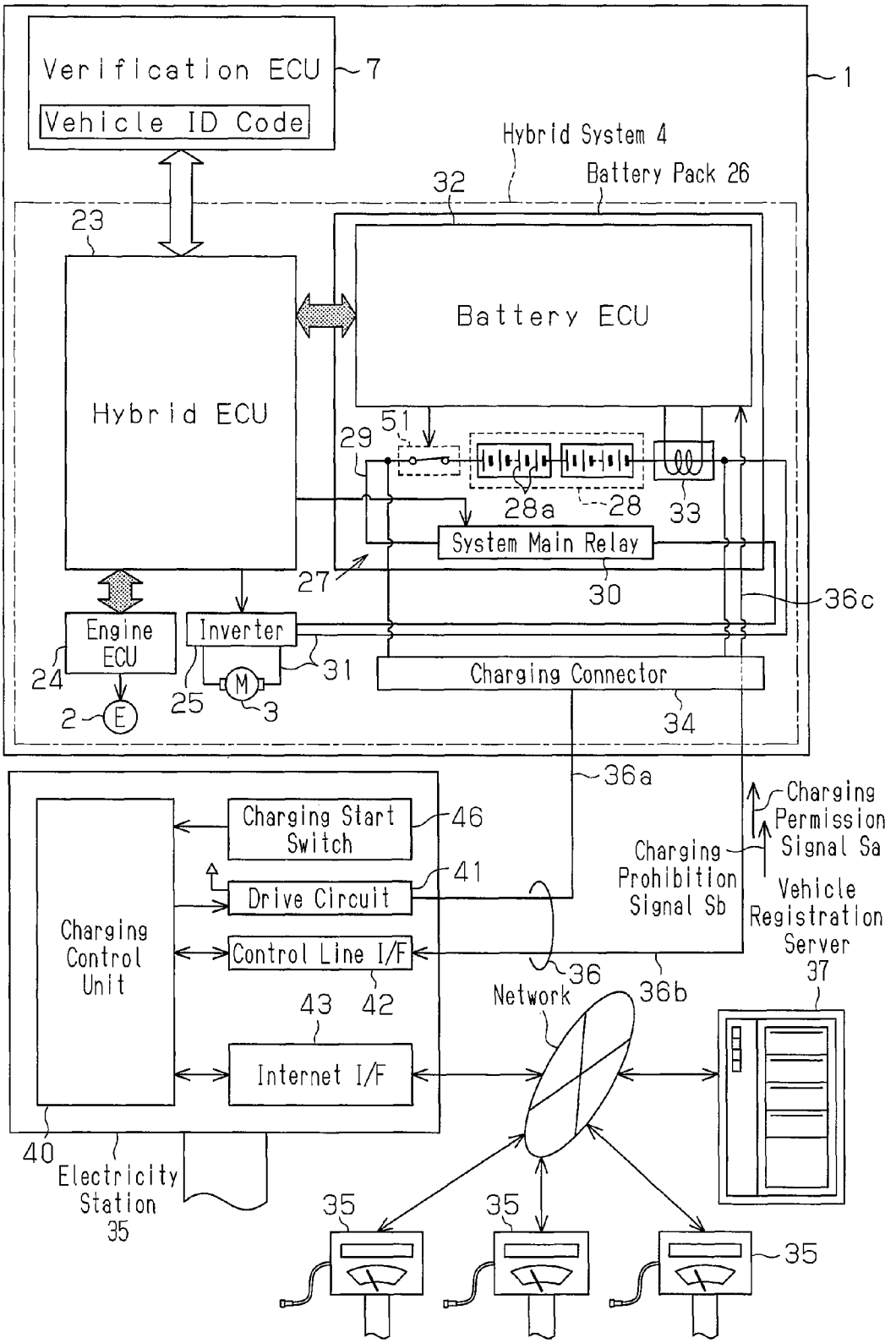
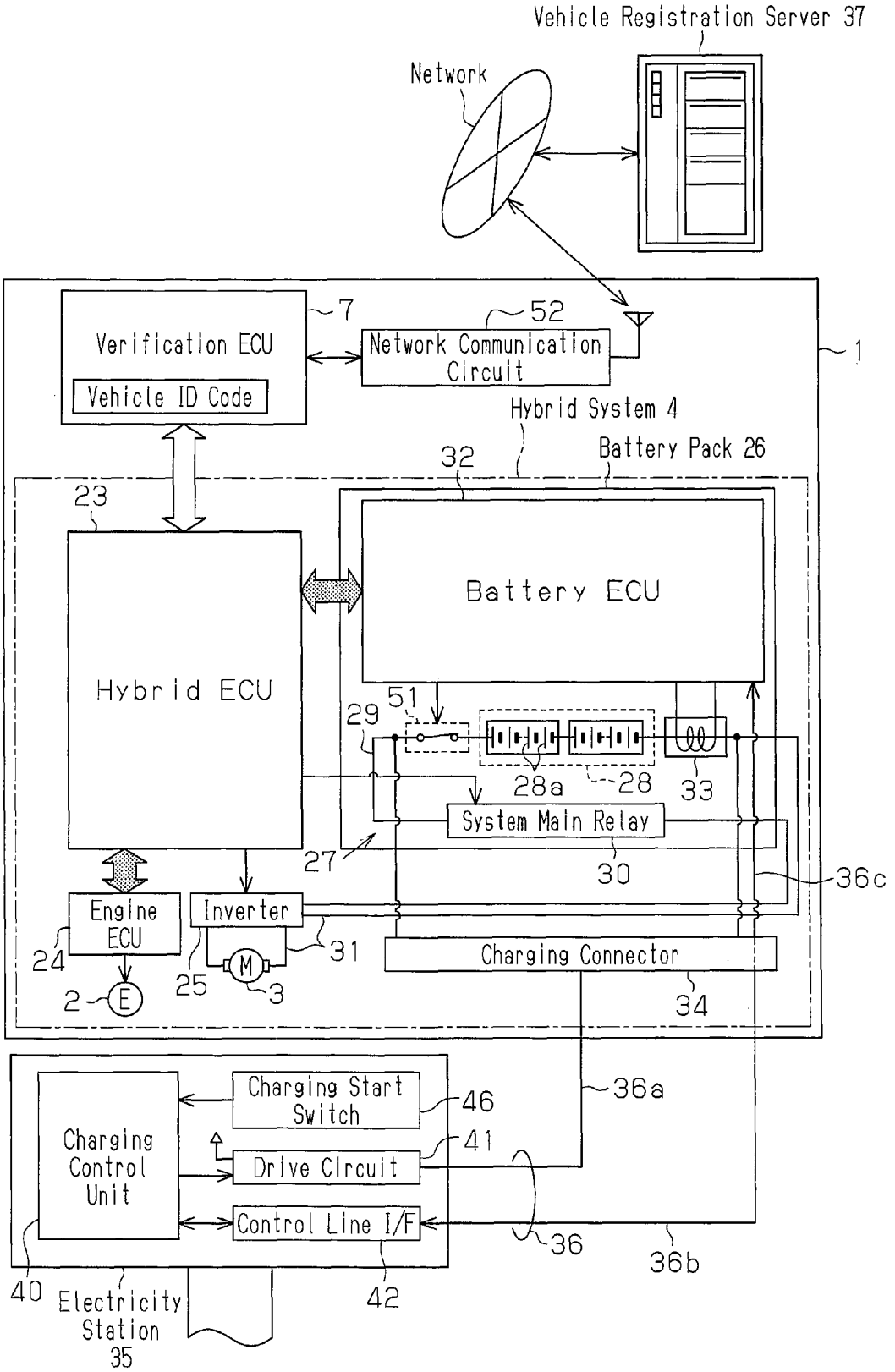

Verification ECU
Vehicle ID Code
7
1
Hybrid System 4
Battery Pack 26
32
23
Battery ECU
Hybrid ECU
51
29
28a
28
33
System Main Relay
27
30
36c
Engine ECU
Inverter
24
25
31
M
3
2
E
Charging Connector
34
36a
Charging Start Switch
46
Charging Permission Signal Sa
Charging Prohibition Signal Sb
41
Drive Circuit
Vehicle Registration Server
37
Charging Control Unit
Control Line I/F
36
Network
36b
43
42
Internet I/F
40
Electricity Station 35
35
35
35

Fig.7


Vehicle Registration Server 37
Network
Verification ECU
Vehicle ID Code
7
52
Network Communication Circuit
1
Hybrid System 4
Battery Pack 26
32
23
Battery ECU
Hybrid ECU
51
29
28a
28
33
System Main Relay
27
30
36c
Engine ECU
Inverter
24
25
31
Charging Connector
2
E
M
3
34
Charging Start Switch
46
36a
Charging Control Unit
41
Drive Circuit
Control Line I/F
36
36b
40
42
Electricity Station 35

REGISTRATION-BASED VEHICLE BATTERY CHARGING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority of International Application PCT/JP2007/063859, filed Jul. 11, 2007, which claims priority to Japanese Application No. 2006-210926, filed Aug. 2, 2006, the entire contents of which are hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a charging system for supplying a charging subject with electricity from a charging device via an electric cable and charging the subject.

BACKGROUND OF THE INVENTION

Over recent years, hybrid vehicles, which use both an engine and a motor as a drive source, and electric vehicles, which use a motor, have become popular vehicle types as an alternative to engine vehicles, which are driven by only an engine. Such an electric vehicle uses a battery that must be charged when the battery voltage becomes low. For example, the battery may be charged by connecting an input of an external charging device, such as a power feed connector, to a household electrical outlet (utility power, alternating current of 100 V) and connecting the output of the charging device to a charging connector of the vehicle. As another option, an electric vehicle may be connected to and charged at an electricity station.

Furthermore, regardless of whether the vehicle is an engine vehicle or an electric vehicle, antitheft measures must be taken. Patent Document 1 describes an example of an antitheft prevention technique that is unique to electric vehicles. In an electric vehicle, a battery is used as a drive source. With the technique described in Patent Document 1, information related to the charging of the vehicle, such as the state of charge of the battery, is collected as driving information. The collected driving information is transmitted to a management center. The management center tracks a stolen vehicle by determining the location of the vehicle from such driving information.

However, even when the state of charge of the stolen vehicle becomes low, the battery of the stolen vehicle can be charged at an electricity station that is located anywhere. Therefore, the battery of the stolen vehicle can be charged periodically. Since the stolen vehicle, which may be charged periodically, can be driven anywhere, it would be extremely difficult to track the stolen vehicle even with the technique described in Patent Document 1.

Patent Document 1: Japanese Laid-Open Patent Publication No. 2005-115667

SUMMARY OF THE INVENTION

The present invention provides a charging system that allows for a charging subject to be easily tracked even when the charging subject is stolen.

A first aspect of the present invention is a charging system. The charging system is provided with a charging subject including a battery and having a unique identification code. A charging device is connected to the battery of the charging subject by an electric cable to charge the battery. A server, connected to either one of the charging device and the charging subject, registers the identification code of the charging subject and manages charging of the charging subject with the charging device. The server obtains the identification code from the charging subject, determines whether or not the obtained identification code is registered in the server, and transmits to the charging device a charging prohibition command for prohibiting charging of the charging subject with the charging device when the obtained identification code is not registered in the server.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram of a charging system according to a first embodiment of the present invention;

FIG. **2** is a detailed block diagram of the charging system of FIG. **1**;

FIG. **3** is a schematic perspective view showing an electricity station;

FIG. **4** is a conceptual diagram of a registered vehicle file stored in a memory of a vehicle registration server shown in FIG. **2**;

FIG. **5** is a conceptual diagram of a charging history stored in the memory of the vehicle registration server shown in FIG. **2**;

FIG. **6** is a schematic block diagram of a charging system according to a second embodiment of the present invention; and

FIG. **7** is a schematic block diagram of a charging system according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

A charging system according to a first embodiment of the present invention will now be discussed in detail with reference to FIGS. **1** to **5**.

As shown in FIG. **1**, when a vehicle is a hybrid vehicle **1**, a hybrid system **4**, which uses both an engine **2** and a motor **3** as a drive source to drive the vehicle wheels, is installed in the body of the vehicle. The hybrid system **4** controls various modes, such as a mode in which the vehicle is driven by the power of the engine transmitted mechanically to the wheels, a mode in which the vehicle is driven by the electric power generated with the power of the engine, a mode in which the wheels are directly driven by both the engine and the motor, and a mode in which the engine is stopped and the vehicle is driven by only the motor. The hybrid vehicle **1** corresponds to a charging subject.

A hands-free system **6** is installed in the hybrid vehicle **1** to allow the doors to be unlocking or the hybrid system to be activated without a mechanical key as long as the drive is carrying a portable device **5**. The hybrid vehicle **1** includes a verification electronic control unit (ECU) **7**, which performs ID verification in the hands-free system **6**. An exterior low-frequency (LF) transmitter **8**, which is located outside the vehicle, an interior LF transmitter **9**, which is located inside the vehicle, and a radio-frequency (RF) receiver **10**, which is located inside the vehicle, are connected to the verification ECU **7**.

Also, a door ECU **11**, which controls the locking and unlocking of the doors, is connected to the verification ECU **7** via an interior bus **12**. A door lock motor **13**, which functions as a drive source for locking and unlocking the doors, is connected to the door ECU **11**. A door courtesy switch **14**, which detects the open or closed state of the doors, is connected to the door ECU **11**. The door ECU **11** receives an

opening signal or a closing signal from the door courtesy switch **14**, and determines whether the doors are currently open or closed.

When the hybrid vehicle **1** is in a parked state (when the hybrid system is deactivated and the doors are locked), the verification ECU **7** forms a communication area outside the vehicle by controlling the exterior LF transmitter **8** to transmit a low frequency request signal Sreq, which requests for an ID in response. When a plurality of exterior LF transmitters **8** are installed outside the vehicle, the exterior LF transmitters **8** each sequentially transmit a request signal Sreq. The verification ECU **7** repeatedly controls the plurality of transmitters **8** to transmit a request signal Sreq. When the portable device **5** enters the exterior communication area, the portable device **5** receives a request signal Sreq. When receiving the request signal Sreq, the portable device **5** transmits a vehicle ID code (identification code) registered in its memory with a vehicle ID signal Sid in an RF band.

When the RF receiver **10** receives the vehicle ID signal Sid while the verification ECU **7** is controlling the exterior LF transmitters **8** to transmit the request signal Sreq, the verification ECU **7** determines that exterior communication has been performed. The verification ECU **7** then performs exterior verification (identification verification) by comparing the vehicle ID code of the portable device **5** with a code sequence registered in the vehicle. When determining that the exterior verification has been established, the verification ECU **7** activates a touch sensor **15**, which has been in a deactivated state. Further, when the touch sensor **15** detects a door handle being touched by a person, the verification ECU **7** transmits a door unlock request signal to the door ECU **11**. In response to the door unlock request signal, the door ECU **11** drives the door lock motor **13** to unlock the locked doors.

When detecting that a lock button **16** on a door handle has been pushed down in a state in which the engine of the hybrid vehicle **1** is stopped and the doors are unlocked, the verification ECU **7** again forms a communication area, which is for performing exterior verification, outside the vehicle (exterior communication area) with the exterior LF transmitters **8**. When an exterior verification has been established, the verification ECU **7** transmits a door lock request signal to the door ECU **11**. In response to the door lock request signal, the door ECU **11** drives the door lock motor **13** to lock the doors.

When the door courtesy switch **14** detects that a driver has entered the vehicle, the verification ECU **7** forms a communication area inside the vehicle (interior communication area) by controlling the interior LF transmitter **9** to transmit a request signal Sreq. When the portable device **5** enters the interior communication area, the portable device **5** returns a vehicle ID signal Sid in response to the request signal Sreq. When the RF receiver **10** receives the vehicle ID signal Sid from the portable device **5** while the verification ECU **7** is controlling the interior LF transmitter **9** to transmit a request signal Sreq, the verification ECU **7** determines that interior communication has been established. The verification ECU **7** then performs interior verification (identification verification) by comparing the vehicle ID code of the portable device **5**, which is located in the vehicle, and the vehicle ID code of the vehicle and determines whether the interior verification has been established. The interior verification may also include immobilizer verification performed by comparing the code of a transponder embedded in the portable device **5** with the code of the vehicle.

A power supply ECU **17**, which controls power supplies for various electric devices installed in the vehicle, is connected to the verification ECU **7** via the bus **12**. The power supply ECU **17** is activated when, for example, the portable device **5** is partially inserted into a key slot **18**, which is arranged next to the steering wheel. A start switch **19**, which is operated to activate or deactivate the hybrid system **4**, is connected to the power supply ECU **17**. In the hybrid vehicle **1**, the hybrid system **4** is activated when the start switch **19** is operated in a state in which the gearshift lever is located at a parking position and the brake pedal is depressed. Also, an ACC relay **20**, which turns the power supplies of accessories on and off, and an IG**1** relay **21** and an IG**2** relay **22**, which switch the ignition system on and off, are connected to the power supply ECU **17**.

A hybrid ECU **23**, which centrally controls the hybrid system **4**, is connected to the verification ECU **7** via the bus **12**. An engine ECU **24**, which controls ignition and fuel ejection of the engine **2**, is connected to the hybrid ECU **23** through controller area network (CAN) communication. The motor **3** is also connected to the hybrid ECU **23** by an inverter **25**. The hybrid ECU **23** controls driving force by calculating an engine output and a motor torque suitable for the driving status based on the accelerator degree, the gearshift position, and output signals from various sensors, and outputs required values to the ECUs including the engine ECU **24** and a battery ECU **32** (described later).

A battery pack **26**, which is accommodated in a single case and unitized, is mounted on the hybrid vehicle **1**. The battery pack **26** contains a battery **27**, which serves as a rechargeable battery component. The battery **27** includes a battery module **28**, which includes a plurality of series-connected cells **28***a*, and a system main relay **30**, which is connected in series to a high-voltage power supply circuit **29** of the battery module **28**. The motor **3** and the inverter **25** are connected to each other by a power cable **31**, which is capable of supplying a large current with a high voltage. In the same manner, the inverter **25** and the battery **27** are connected to each other by another power cable **31**, which is capable of supplying a large current with a high voltage. The system main relay **30** is connected to the hybrid ECU **23**. The system main relay **30** connects or disconnects the high-voltage power supply circuit **29** in response to a command from the hybrid ECU **23**. The battery **27** corresponds to a rechargeable battery.

The battery pack **26** contains the battery ECU **32**, which monitors the state of charge of the battery **27**. The battery ECU **32** is connected to the hybrid ECU **23** through CAN communication. The battery ECU **32** operates in accordance with a control program for monitoring the state of charge stored in its memory (not shown) and monitors the state of charge or charged amount of the battery **27**.

A current sensor **33**, which detects the amount of current flowing through the high-voltage power supply circuit **29**, is connected to a cable of the high-voltage power supply circuit **29**. The current sensor **33** is connected to the battery ECU **32** and provides a detection signal in accordance with the value of current flowing through the high-voltage power supply circuit **29** to the battery ECU **32**. The battery ECU **32** monitors the state of charge of the battery **27** based on the detection signal from the current sensor **33** and provides the monitoring result to the hybrid ECU **23** in response to a state of charge notification request from the hybrid ECU **23**. The hybrid ECU **23** determines the state of charge of the battery **27** based on the monitoring result provided from the battery ECU **32**.

The battery pack **26** includes a charging connector **34**, which is used as an inlet for electricity when charging the battery **27**. The charging connector **34** is connectable to an electricity station **35** via a charging cable **36**. The electricity station **35** supplies power to the battery **27** to charge the battery **27**. The charging cable **36** is an electric cable extending from the electricity station **35**. To charge the battery **27**, a

distal end of the charging cable **36** is connected to the charging connector **34**. When the electricity station **35** starts a charging operation, current flows from the electricity station **35** to the battery **27** through the charging cable **36** and the charging connector **34**. This charges the battery **27**. The electricity station **35** corresponds to a charging device. The charging cable **36** corresponds to an electric cable.

The electricity station **35** is connected to a vehicle registration server **37** so as to enable network communication between the electricity station **35** and the vehicle registration server **37**. The hybrid vehicle **1** has a vehicle ID code registered in the vehicle registration server **37**. The vehicle ID code is registered in the vehicle registration server **37** by applying for registration to, for example, a motor vehicle official or a security company. The network communication between the electricity station **35** and the vehicle registration server **37** may be in performed in various forms, such as through communication with the Internet, a Wide Area Network (WAN), or a Local Area Network (LAN). The communication may be performed through wired and wireless communication. The vehicle registration server **37** corresponds to a server.

As shown in FIG. **2**, the charging cable **36** includes a power line **36***a* and a control line **36***b*. The power line **36***a* is an electric line capable of supplying a large current with a high voltage. The control line **36***b* is used to transmit a control command from the electricity station **35** to the battery ECU **32**. As shown in FIG. **3**, a power feed connector **39**, which has a contact terminal **38**, is arranged on a distal end of the charging cable **36**. To charge the battery **27** with the electricity station **35**, the power feed connector **39** is connected to the charging connector **34**. When the charging cable **36** is connected to the charging connector **34**, the control line **36***b* is connected to a communication line **36***c* of a control system extending from the charging connector **34** to the battery ECU **32**.

As shown in FIG. **2**, the electricity station **35** includes a charging control unit **40**, which centrally controls the electricity station **35**. The charging control unit **40** includes devices, such as a central processing unit (CPU), a ROM (read-only memory), and a random-access memory (RAM) (none shown), and operates based on a control program stored in the ROM. The charging control unit **40** is connected to the power line **36***a* of the charging cable **36** via a drive circuit **41** and connected to the control line **36***b* via a control line interface **42**. The charging control unit **40** is also connected through a network to the vehicle registration server **37** via an Internet interface **43**, through which data is input and output.

When the electricity station **35** is operated to start charging, the charging control unit **40** provides an ID check request to the hybrid ECU **23** via the control line **36***b*, the communication line **36***c*, and the battery ECU **32**. In response to the request, the hybrid ECU **23** transmits the vehicle ID code obtained from the verification ECU **7** to the charging control unit **40** of the electricity station **35** via the battery ECU **32**, the communication line **36***c*, and the control line **36***b*. When receiving the vehicle ID code from the hybrid ECU **23**, the charging control unit **40** performs registered ID verification by determining whether the received vehicle ID code has been registered in the vehicle registration server **37**. When the registered ID verification is established, the charging of the battery **27** is permitted. In such a case, the charging control unit **40** charges the battery **27** with current supplied through the power line **36***a*.

Encrypted communication is performed during data communication between the battery ECU **32** and the hybrid ECU **23** when the electricity station **35** obtains the vehicle ID code from the hybrid ECU **23**. Encrypted communication is also performed during network communication between the electricity station **35** and the vehicle registration server **37**. The encrypted communication is based on, for example, a challenge-response technique using a random number generated when, for example, data is transmitted. With this technique, the hybrid vehicle **1** and the electricity station **35** each encrypts the random number with its own encryption key. Authentication is then performed by determining whether the encrypted value obtained by the hybrid vehicle **1** and the encrypted value obtained by the electricity station **35** are the same.

The operation of the charging system in the first embodiment will now be described.

First, a registration process for registering the vehicle ID code stored in the verification ECU **7** of the hybrid vehicle **1** into the vehicle registration server **37** is performed. Referring to FIG. **4**, through the registration process, the vehicle ID code of the registered vehicle is written to an ID code field **45***a* of a registered vehicle file **45**, which is stored in a memory **44** of the vehicle registration server **37**. In addition to the ID code field **45***a* to which the vehicle ID code is written, the registered vehicle file **45** includes an owner information field **45***b*, into which details of the vehicle owner are written, and a stolen vehicle registration field **45***c*.

The charging start operation of the electricity station **35** is performed by, for example, turning on a charging start switch **46**, which is arranged on the electricity station **35**, when the power feed connector **39** of the charging cable **36** is connected to the charging connector **34** of the hybrid vehicle **1**. When detecting the charging start operation, the charging control unit **40** transmits an ID check request to the battery ECU **32** via the control line **36***b* and the communication line **36***c*.

When receiving the ID check request, the battery ECU **32** transfers the received request to the hybrid ECU **23**. In response to the ID check request transferred from the battery ECU **32**, the hybrid ECU **23** transmits the request to the verification ECU **7**. In response to the ID check request transmitted from the hybrid ECU **23**, the verification ECU **7** returns its registered vehicle ID code to the hybrid ECU **23**. The hybrid ECU **23** transmits the vehicle ID code from the verification ECU **7** to the charging control unit **40** of the electricity station **35** via the battery ECU **32**, the communication line **36***c*, and the control line **36***b*.

The charging control unit **40** performs encrypted communication based on the above challenge-response technique during data communication between the hybrid ECU **23** and the electricity station **35**. In detail, when transmitting the ID check request to the hybrid ECU **23**, the charging control unit **40** generates a predetermined random number, adds the random number to the data sequence of the ID check request, and transmits the resulting data group to the hybrid ECU **23** as the ID check request.

The hybrid ECU **23** encrypts the random number included in the data group (ID check request) with its own encryption key. The hybrid ECU **23** adds the encrypted random number to the code sequence of the vehicle ID code and returns the resulting data group to the charging control unit **40** of the electricity station **35** as the vehicle ID code.

Subsequently, the charging control unit **40** encrypts the generated random number with its own encryption key and compares the encrypted random number with the encrypted random number in the vehicle ID code returned from the hybrid ECU **23**. When the hybrid ECU **23** to which the data has been transferred corresponds to the electricity station **35**, the encryption keys of the hybrid ECU **23** and the electricity station **35** are identical to each other. In such a case, the two encrypted random numbers should be the same. Thus, when

the random number encrypted by the hybrid vehicle **1** and the random number encrypted by the electricity station **35** are the same, the encrypted communication is authenticated. When the encrypted communication has been authenticated, the charging control unit **40** accepts the vehicle ID code.

The encrypted communication based on the challenge-response technique includes encryption performed by replacing some bits of a random number and performing an addition operation and an exclusive-OR operation of the random number in which some bits have been replaced and an encryption key. Another example of encrypted communication includes conjugating or adding a random number and an encryption key and subjecting the addition result to a Hash function, such as Message Digest Algorithm 5 (MD5) or Secure Hash Algorithm (SHA). The encrypted communication method is of course not limited to these methods, and various types of encryption methods may be used.

The charging control unit **40** transmits the vehicle ID code obtained from the vehicle to the vehicle registration server **37** through network communication. The vehicle registration server **37** performs registered ID verification by determining whether the vehicle ID code has been registered in its memory **44**, and determines whether charging is permitted based on the verification result. When determining that the vehicle ID code has been registered in its memory **44**, the vehicle registration server **37** returns to the charging control unit **40** by network communication a message indicating that the vehicle ID code has been registered.

The charging control unit **40** determines that the registered ID verification has been established based on the message from the vehicle registration server **37** indicating that the vehicle ID code has been registered. The charging control unit **40** then sets the vehicle to a charging permission state in which charging of the vehicle is permitted. The charging control unit **40** then starts supplying the charging current from the power line **36***a* to the battery **27** of the vehicle to start charging the battery **27**.

During the battery charging, the charging control unit **40** monitors the charged electricity amount of the battery **27** by constantly monitoring the voltage across the battery **27**. When determining that the battery **27** reaches a fully charged state, the charging control unit **40** stops supplying current from the power line **36***a* to stop charging the battery **27**.

When the vehicle ID code of the verification ECU **7** is not stored in the memory **44** of the vehicle registration server **37** in the registered ID verification, the charging control unit **40** receives from the vehicle registration server **37** a message indicating that the vehicle ID code of the vehicle is not registered (charging prohibition command). In such a case, the charging control unit **40** is set in a charging prohibition state in which charging of the vehicle is prohibited. In such a case, the charging control unit **40** prohibits current from being supplied from the power line **36***a* to the battery **27** and does not charge the battery **27** even when the charging start operation of the electricity station **35** is performed.

The encrypted communication based on the above challenge-response technique is used to transmit data through network communication between the electricity station **35** and the vehicle registration server **37**. Instead of the challenge-response technique, the encrypted communication may be performed based on common key cryptography, such as the Data Encryption Standard (DES) or Advanced Encryption Standard (AES), or public key cryptography, such as RSA. Further, a hybrid technique combining common key cryptography and public key cryptography may also be used.

Accordingly, when charging the battery **27** of the hybrid vehicle **1** with the electricity station **35**, the electricity station **35** is activated only when the vehicle ID code of the charging subject vehicle is registered in the vehicle registration server **37**. That is, the vehicle ID code of the charging subject vehicle must be registered in the vehicle registration server **37** or else the battery **27** of the vehicle cannot be charged. Thus, even if the hybrid vehicle **1** is stolen by a thief, it cannot be charged by the electricity station **35** unless the vehicle ID code of the stolen vehicle is registered in the vehicle registration server **37**. This system decreases the number of electricity stations **35** that can be used to charge the stolen vehicle and consequently shortens the distance by which the stolen vehicle can be driven. As a result, the stolen vehicle may be tracked within a narrower range. This enables the stolen vehicle to be tracked more easily and improves the possibility of the stolen vehicle being found.

Further, if an unauthorized operator who has not taken the required vehicle ID code registration procedures with the vehicle registration server **37** tries to charge the battery **27** of the vehicle with the electricity station **35**, the electricity station **35** will not start the charging operation. As a result, unauthorized charging of the battery **27** with the electricity station **35** becomes difficult. This effectively prevents electricity from being stolen.

Additionally, the vehicle registration server **37** detects the charging operation of the battery **27** performed by the electricity station **35** and accumulates the charging history in its memory **44**. In detail, when the electricity station **35** is used to charge the battery **27**, the charging control unit **40** transmits a station ID code (device-number code) unique to the electricity station **35** to the vehicle registration server **37** together with a message indicating that the charging has been started. In response to the charging start message, referring to FIG. **5**, the vehicle registration server **37** writes to the memory **44**, as the charging history, the vehicle ID code of the vehicle for which the charging operation is performed, the charging time and date, and the station ID code of the electricity station **35** used to charge the vehicle.

Thus, when the electricity station **35** is used to charge the registered vehicle, the charging history of the vehicle is accumulated in the vehicle registration server **37**. The charging history indicates when and where each registered vehicle has been charged. Therefore, if a vehicle is stolen and the stolen vehicle is charged by an electricity station **35**, by managing the charging history, the electricity station **35** would used to charge the stolen vehicle would be located. As a result, the current position of the stolen vehicle can be determined. This enables the stolen vehicle to be tracked more easily and provides the vehicle with an effective antitheft measure.

Referring to FIG. **4**, the vehicle registration server **37** may also register information on a stolen vehicle. For example, a stolen vehicle is registered in the vehicle registration server **37** by writing information on the stolen vehicle into the stolen vehicle registration field **45***c* so that the stolen vehicle information is associated with the corresponding vehicle ID code in the registered vehicle file **45**. The stolen vehicle may be registered, for example, through network communication using a communication terminal, such as a personal computer or a cellular phone, or by notifying a motor vehicle official or a security company that manages the vehicle registration server **37** of the stolen vehicle using a phone or the like.

When charging the battery **27** of the vehicle with the electricity station **35**, the vehicle registration server **37** first determines whether the vehicle ID code of the charging subject vehicle has been registered in the memory **44**. The vehicle registration server **37** also determines whether the charging subject vehicle identified by the vehicle ID code is a stolen vehicle by referring to the stolen vehicle registration field **45***c*

of the registered vehicle file **45**. If the charging subject vehicle is a stolen vehicle, the vehicle registration server **37** transmits a message indicating that the vehicle is a stolen vehicle (or a message indicating that the vehicle ID code has not been registered) together with the corresponding vehicle ID code to the electricity station **35**. In response to the message indicating the stolen vehicle, the charging control unit **40** is set in a charging prohibition state in which charging of the vehicle is prohibited. In this state, even when the charging start operation of the electricity station **35** is performed, current is not supplied from the power line **36***a* to the battery **27**. Thus, the battery **28** is not charged.

If a registered vehicle is stolen, the registered vehicle can be registered as a stolen vehicle in the vehicle registration server **37**. This disables charging of the battery **27** with the electricity station **35**. Without the battery **27** being charged, the battery **27** will drain after a while and the vehicle will stop. In such a case, a thief who has stolen the vehicle will ultimately have to leave the vehicle. This provides the vehicle with an effective antitheft measure.

The charging system of the first embodiment has the advantages described below.

(1) When charging the battery **27**, the vehicle cannot be charged by the electricity station **35** unless the vehicle ID code of the vehicle is registered in the registration server **37**. Thus, even if the hybrid vehicle **1** is stolen by a thief, the hybrid vehicle **1** cannot be charged by the electricity station **35**, which is managed by the vehicle registration server **37**. This system decreases the number of public electricity stations **35** that can be used to charge the stolen vehicle and consequently shortens the distance by which the stolen vehicle can be driven. As a result, the stolen vehicle can be tracked within a narrower range. This enables the stolen vehicle to be tracked more easily and increases the possibility of the stolen vehicle being found.

(2) The battery **27** cannot be charged by the electricity station **35** unless the vehicle ID code is registered in advance in the vehicle registration server **37**. Thus, even if an unauthorized user who has not registered the ID code-tries to use the electricity station **35**, the electricity station **35** cannot be activated. This makes it difficult to perform unauthorized charging with the electricity station **35** and prevents electricity from being stolen by a thief.

(3) The vehicle registration server **37**, which has high data processing capacity, performs the ID verification. This shortens the time required for the ID verification. Also, the electricity station **35** performs the registered ID verification. This eliminates the need for installing a communication mechanism for ID-verification on the vehicle. Accordingly, the structures of components associated with the communication system and components associated with the computer system of the vehicle are prevented from becoming complicated.

(4) When performing charging with the electricity station **35**, the charging history is accumulated in the vehicle registration server **37**. The charging history indicates when the vehicle was charged by the electricity station **35**. If the electricity station **35** is used without an authorized user's permission, the charging history indicates to the authorized user such unauthorized use of the electricity station **35**. This system prevents unauthorized charging. The charging history also indicates which electricity station **35** was used. Accordingly, when the battery **27** of a stolen vehicle is charged by an electricity station **35**, the location of the electricity station **35** can be determined as the current location of the stolen vehicle. This enables the stolen vehicle to be tracked and provides the vehicle with a more effective antitheft measure.

(5) When a stolen vehicle is registered in the vehicle registration server **37**, even if a thief tries to use the electricity station **35** to charge the battery **27** of the stolen vehicle, the electricity station **35** cannot be set in a charging permission state. The electricity station **35** is instead set in a charging prohibition state in which charging of the battery **27** of the stolen vehicle is prohibited. Accordingly, the battery **27** of the stolen vehicle registered in the vehicle registration server **37** will drain after a while, and the vehicle will stop. In that case, the thief who has stolen the vehicle will ultimately leave the vehicle. The stolen vehicle registration will therefore provide the vehicle with a more effective antitheft measure.

(6) Encrypted communication is performed during the data communication between the hybrid vehicle **1** and the electricity station **35** and the data communication between the electricity station **35** and the vehicle registration server **37**. This makes it difficult to hamper verifications. Thus, unauthorized charging is effectively prevented.

Second Embodiment

A charging system according to a second embodiment of the present invention will now be described with reference to FIG. **6**. The second embodiment describes another form of the registered ID verification described in the first embodiment. The components of the second embodiment that are the same as the components of the first embodiment are given the same reference numerals as those components and are therefore not described in detail.

Referring to FIG. **6**, a switch **51** for energizing and de-energizing the high-voltage power supply circuit **29**, is connected in series to the high-voltage power supply circuit **29**. A series-connected circuit including the battery module **28**, the current sensor **33**, and the switch **51** are connected in series to the charging connector **34**. The switch **51**, which is connected to the battery ECU **32**, is turned on and off based on a command from the battery ECU **32**. The switch **51** is normally on. The switch **51** is turned off when the battery ECU **32** receives a charging prohibition command from the electricity station **35**. When the switch **51** is turned off, charging is prohibited.

When detecting that an operation for turning on the charging start switch **46** has been performed in a state in which the charging cable **36** is connected to the charging connector **34** of the vehicle, the charging control unit **40** starts to supply current from the power line **36***a* to the battery **27** regardless of the registered ID verification result. At the same time as when starting the current supply, the charging control unit **40** transmits an ID check request to the hybrid ECU **23** via the control line **36***b*, the communication line **36***c*, and the battery ECU **32**, and obtains a vehicle ID code registered in the verification ECU **7**.

The charging control unit **40** transmits the vehicle ID code transmitted from the vehicle to the vehicle registration server **37** through network communication. The vehicle registration server **37** determines whether the vehicle ID code has been registered in the memory **44**. When receiving a message from the vehicle registration server **37** indicating that the vehicle ID code has been registered, the charging control unit **40** determines that the registered ID verification has been established and sets a charging permission state in which charging of the vehicle is permitted.

The charging control unit **40** set in the charging permission state transmits a charging permission signal Sa to the battery ECU **32** via the control line **36***b* and the communication line **36***c*. In response to the charging permission signal Sa, the battery ECU **32** keeps the switch **51** on to keep the high-voltage power supply circuit **29** closed As a result, charging current is supplied from the electricity station **35** to the battery **27** via the power line **36***a* to charge the battery **27**.

When receiving a message from the vehicle registration server **37** indicating that the vehicle ID code has not been registered, the charging control unit **40** determines that the registered ID verification has not been established and is set in a charging prohibition state for prohibiting charging of the vehicle.

The charging control unit **40** set in the charging prohibition state transmits a charging prohibition signal Sb to the battery ECU **32** via the control line **36***b* and the communication line **36***c*. In response to the charging prohibition signal Sb, the battery ECU **32** turns off the activated switch **51** to de-energize the high-voltage power supply circuit **29**. As a result, the charging current supplied from the electricity station **35** via the power line **36***a* does not flow to the battery **27** and the battery **27** is not charged. When detecting that an operation for stopping charging with the electricity station **35** has been performed via the control line **36***b* and the communication line **36***c*, the battery ECU **32** returns the switch **51** to the activated state.

In the second embodiment described above, when the vehicle ID code is not registered in the vehicle registration server **37**, that is, when the registered ID verification is not established, the high-voltage power supply circuit **29** is set as an open circuit. As a result, even when the electricity station **35** is designed to start supplying current at the same time as when the charging start switch **46** of the electricity station **35** is turned on, this system prevents the charging current from flowing to the battery **27** when registered ID verification is not established. The electricity station **35** does not necessarily have to start supplying current at this timing.

In addition to advantages (1) to (6) of the first embodiment, the charging system of the second embodiment has the advantage described below.

(7) The switch **51** is turned off when the registered ID verification is not established. Thus, even if the electricity station **35** is designed to start supplying current when the charging start switch **46** of the electricity station **35** is pushed regardless of the result of the registered ID verification, this system prevents current from flowing to the battery **27**.

Third Embodiment

A charging system according to a third embodiment of the present invention will now be described with reference to FIG. **7**. The third embodiment describes another form of the registered ID verification described in the second embodiment. The components of the third embodiment that are the same as the components of the second embodiment are given the same reference numerals as those components and will not be described in detail.

As shown in FIG. **7**, a network communication circuit **52**, which performs wireless network communication with the vehicle registration server **37**, is installed in the hybrid vehicle **1**. The network communication circuit **52** is connected to the verification ECU **7** and operates based on a command from the verification ECU **7**. The network communication circuit **52** can perform wireless LAN communication with, for example, a hot spot installed in a building. The network communication circuit **52** transmits and receives data to and from the vehicle registration server **37** through network communication performed via a wireless LAN.

When detecting that an operation for turning on the charging start switch **46** has been performed in a state in which the charging cable **36** is connected to the vehicle charging connector **34**, the charging control unit **40** starts to supply current from the power line **36***a* to the battery **27**. The charging control unit **40** further transmits an ID check request to the hybrid ECU **23** via the control line **36***b*, the communication line **36***c*, and the battery ECU **32**. In response to the ID check request, the hybrid ECU **23** sends the received request to the verification ECU **7**.

In response to the ID check request from the hybrid ECU **23**, the verification ECU **7** transmits its registered vehicle ID code to the vehicle registration server **37** via a network from the network communication circuit **52**. The vehicle registration server **37** determines whether the vehicle ID code transmitted from the verification ECU **7** is registered in its memory **44**. When the vehicle ID code is registered, the vehicle registration server **37** returns a message to the verification ECU **7** indicating that the vehicle ID code is registered via the network and the circuit **52**.

The verification ECU **7** transfers the message indicating that the vehicle ID code has been registered to the battery ECU **32** via the hybrid ECU **23**. In response to the message indicating that the vehicle ID code has been registered, the battery ECU **32** is set in a charging permission state in which charging of the battery **27** is permitted.

The battery ECU **32** set in the charging permission state keeps the switch **51** on to keep the high-voltage power supply circuit **29** closed. As a result, the charging current is supplied from the electricity station **35** to the battery **27** via the power line **36***a* to charge the battery **27**.

When receiving a message from the vehicle registration server **37** indicating that the vehicle ID code is not registered, the verification ECU **7** transfers the message to the battery ECU **32** via the hybrid ECU **23**. In response to the message indicating that the vehicle ID code is not registered, the battery ECU **32** is set in a charging prohibition state in which the battery **27** cannot be charged.

The battery ECU **32** set in the charging prohibition state turns off the activated switch **51** to de-energize the high-voltage power supply circuit **29**. As a result, the charging current supplied from the electricity station **35** via the power line **36***a* does not flow to the battery **27**, and the battery **27** is not charged.

In the third embodiment, the verification communication mechanism for performing the registered ID verification is installed in the vehicle. This eliminates the need to install a communication mechanism for ID verification on the electricity station **35** and simplifies the structure of the electricity station **35**. Further, the verification communication mechanism installed in the vehicle, which is located closer to the vehicle owner than a verification communication mechanism installed in an electricity station **35** at public facilities will be less likely to be replaced in an unauthorized manner. Installing the verification communication mechanism in the vehicle will therefore more effectively prevent unauthorized charging.

In addition to the advantages (1) to (7) of the first and second embodiments, the charging system of the third embodiment has the advantage described below.

(8) The registered ID verification is performed between the hybrid vehicle **1** and the vehicle registration server **37**. This eliminates the need to arrange a communication mechanism for ID verification in the electricity station **35**. This simplifies the structure of the electricity station **35** and eliminates the need to drastically change the design of the electricity station **35**.

The above embodiments may be modified in the following forms.

In the first to third embodiments, the server **37** does not necessarily have to perform the registered ID verification to determine whether the hybrid vehicle **1** is permitted to be charged using the electricity station **35**. For example, when a stolen vehicle is registered in the server **37**, the server **37** may

transmit, together with the vehicle ID code of the stolen vehicle, a charging prohibition message (charging prohibition command) indicating to prohibit charging of a vehicle having that vehicle ID code. The electricity station **35** stores the command together with the vehicle ID code and determines whether charging is permitted in accordance with such storage contents. More specifically, when the vehicle ID code of the hybrid vehicle **1** (charging subject) is a code sequence of the vehicle for which the charging prohibition command has been issued, the electricity station **35** prohibits the vehicle from being charged. This eliminates the need to perform the processing of comparing all of the code sequences registered in the server **37** with the code sequence of the charging subject vehicle, which would otherwise be required whenever the hybrid vehicle **1** is charged by the electricity station **35**. As a result, the ID verification requires only simple processing.

In the first to third embodiments, power line communication (PLC) performed using the power line **36***a* as a data transfer path may be used as the data communication between the hybrid vehicle **1** and the electricity station **35**. In this case, the control line **36***b* is eliminated, and the number of cables connecting the hybrid vehicle **1** and the electricity station **35** is reduced. This reduces the cost for components required by cables.

In the first to third embodiments, the registered ID verification does not necessarily have to be performed by the vehicle registration server **37**. The vehicle registration server **37** may transfer a list of its centrally managed vehicle ID codes to the hybrid vehicle **1** or to the electricity station **35**. In this case, instead of the vehicle registration server **37**, the hybrid vehicle **1** or the electricity station **35** performs the registered ID verification.

In the first to third embodiments, the items of the charging history is not limited to the vehicle ID code, the charging time and date, and the station ID code of the electricity station **35**, but may further include the charging time or the state of charge of the battery when starting charging. The charging history may also be stored in the electricity station **35**.

In the first to third embodiments, the operation of prohibiting the battery **27** from being charged when the registered ID verification is not established may be performed by either stopping the current supply from the electricity station **35** or by turning off the switch **51** connected to the battery **27** to cut the current flowing through the battery **27** (current flows from the electricity station **35**).

In the first to third embodiments, different vehicle ID codes may be registered in the verification ECU **7** between the ID verification performed when the doors are unlocked or the hybrid system is activated and the registered ID verification performed when the determination as to whether charging is permitted is performed. In this case, for example, a special ID code for the registered ID verification is registered in the verification ECU **7**.

In the first to third embodiments, the vehicle ID code registered in the hybrid vehicle **1** is not limited to a fixed value and may be rewritable.

In the first to third embodiments, the charging device is not limited to the electricity station **35** and may be a household charging device installed in a house.

In the first to third embodiments, the vehicle is not limited to the hybrid vehicle **1** and may be an electric vehicle driven only by a motor. Also, the charging subject is not be limited to a vehicle and may be any apparatus or device driven by the battery **27**, which functions as a drive source.

In the second and third embodiments, the switch for connecting or disconnecting the high-voltage power supply circuit **29** is not limited to the mechanical contact switch **51**.

The invention claimed is:

1. A charging system comprising:

a vehicle including a verification ECU in which a unique vehicle identification code is registered, a battery ECU connected to the verification ECU in a communicable manner, and a battery connected to the battery ECU;

a charging device, connectable to the battery and battery ECU of the vehicle by an electric cable, in which the charging device transmits a vehicle identification code check request to the verification ECU through the electric cable and the battery ECU, and the verification ECU reads the vehicle identification code in response to the check request; and

a server, connected to either one of the charging device and the vehicle, for managing charging of the vehicle with the charging device and registering the vehicle identification code;

wherein the server obtains from the vehicle the vehicle identification code read by the verification ECU, determines whether or not the obtained vehicle identification code is registered in the server, and transmits to the charging device a charging prohibition command for prohibiting charging of the vehicle with the charging device when the obtained vehicle identification code is not registered in the server;

the server further registers the vehicle identification code in association with whether or not charging of the vehicle with the charging device is permitted, and when obtaining from the vehicle the vehicle identification code for which charging is registered as not permitted, the server transmits the obtained vehicle identification code and the charging prohibition command to the charging device; and

the charging device prohibits charging of the vehicle identified by the vehicle identification code related with the charging prohibition command.

2. The charging system according to claim **1**, wherein:

the server is connected to the charging device; and

the charging device receives the charging prohibition command directly from the server.

3. The charging system according to claim **1**, wherein:

the server is connected to the vehicle; and

the charging device receives the charging prohibition command from the server via the vehicle.

4. The charging system according to claim **1**, wherein the server further accumulates a charging history including at least the vehicle identification code and a charging time.

5. The charging system according to claim **4**, wherein:

the charging device transmits a device number code unique to the charging device to the server when charging the vehicle; and

the server stores the device number code transmitted from the charging device as the location of the charging device to accumulate charging locations of the vehicle as the charging history.

6. The charging system according to claim **1**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

7. The charging system according to claim **5**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

8. The charging system according to claim **2**, wherein the server further accumulates a charging history including at least the vehicle identification code and a charging time.

9. The charging system according to claim **8**, wherein:

the charging device transmits a device number code unique to the charging device to the server when charging the vehicle; and

the server stores the device number code transmitted from the charging device as the location of the charging device to accumulate charging locations of the vehicle as the charging history.

10. The charging system according to claim **9**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

11. The charging system according to claim **3**, wherein the server further accumulates a charging history including at least the vehicle identification code and a charging time.

12. The charging system according to claim **11**, wherein:

the charging device transmits a device number code unique to the charging device to the server when charging the vehicle; and

the server stores the device number code transmitted from the charging device as the location of the charging device to accumulate charging locations of the vehicle as the charging history.

13. The charging system according to claim **12**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

14. The charging system according to claim **2**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

15. The charging system according to claim **3**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

16. The charging system according to claim **4**, wherein:

the electric cable includes a power line for supplying power from the charging device to the vehicle; and

the vehicle and the charging device communicate data through power line communication using the power line as a data transfer path.

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