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(54) **METHOD OF ACHIEVING AN OPTIMAL OPERATING POINT IN BATTERY SWAPPING PROCESS**

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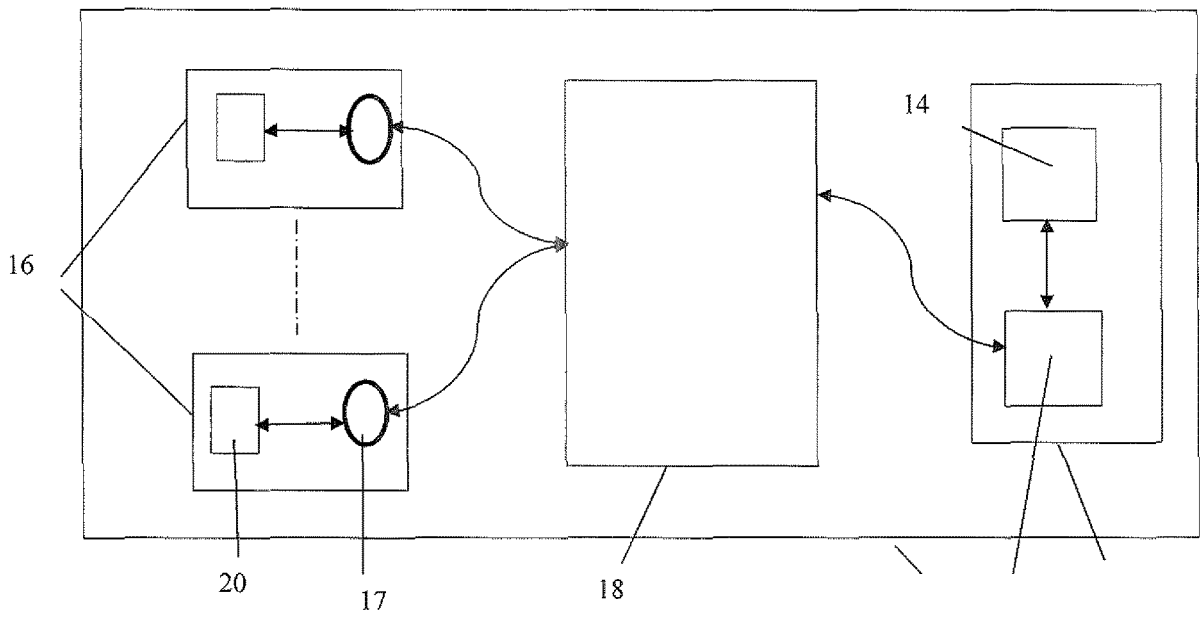
(57) **ABSTRACT**

A method of achieving an optimal operation point for swapping a battery in an electric vehicle includes sensing a battery voltage level in the electric vehicle when the electric vehicle is in a functional mode and determining a distance that the electric vehicle can travel based on the sensed battery voltage level. The method further includes detecting at least one battery swapping center in a predefined distance, when the battery voltage level is below a threshold value. The method further includes providing the at least one battery-swapping center information regarding the detected battery voltage level of the electric vehicle for swapping of the battery of the electric vehicle.



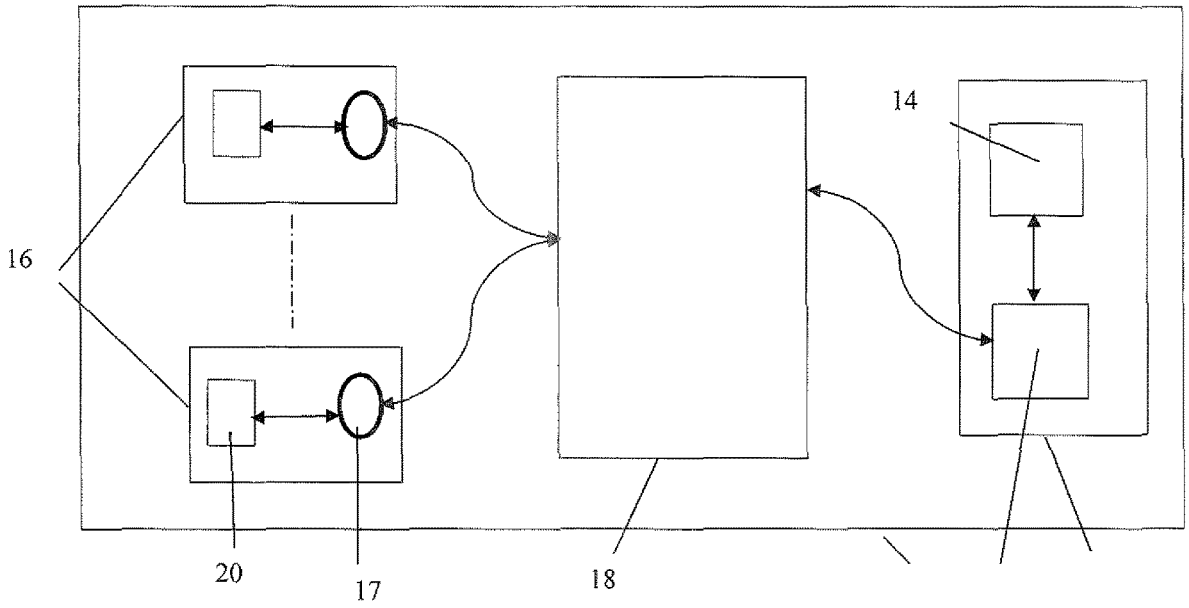


Figure 1

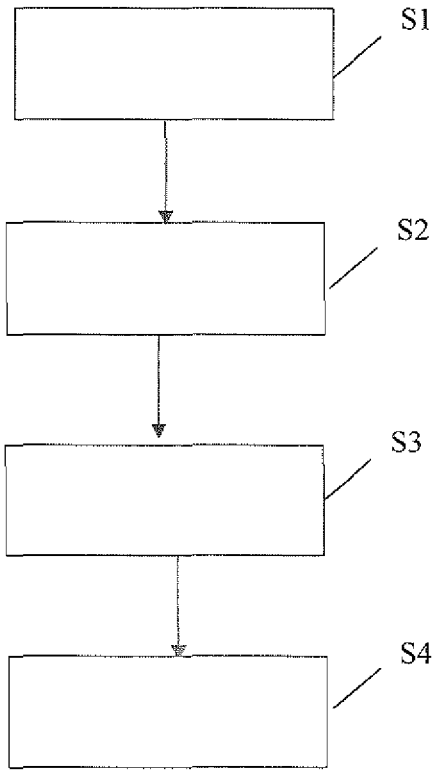


Figure 2

METHOD OF ACHIEVING AN OPTIMAL OPERATING POINT IN BATTERY SWAPPING PROCESS

FIELD OF THE INVENTION

[0001] This invention relates to the field of a method of swapping a battery in an electric vehicle. The invention further relates in achieving an efficient anti optimal operational point of swapping process through a learning technique.

BACKGROUND OF THE INVENTION

[0002] Battery swapping of electric vehicles has been touted as a solution that can help address some of the key hurdles to mass adoption of electric vehicles. However, given the vast number of industry players dealing with manufacturing and retailing of both vehicles and batteries, the success of battery swapping hinges on the sustainability of an ecosystem in which multiple stakeholders can participate to achieve sustainable regions of operational conditions.

[0003] Prior art patent application US 20120248868 discloses a battery car employed in conjunction with a battery car station employs a swappable battery configuration. Access to the batteries of differing types is controlled through a switch control processor selectively coupling batteries tc one or more power grids depending upon a given battery's sensed energy. Access to the batteries of differing types is based on demands of vehicle operation. Based on such configuration, a swappable battery car station in communication with the battery car might then selectively replace batteries as needed.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWING

[0004] Different modes of the invention are disclosed in detail in the description and illustrated in the accompanying drawing:

[0005] FIG. **1** illustrates a system for battery swapping in an electric vehicle in accordance to one embodiment of the invention; and

[0006] FIG. **2** illustrates a flow chart of a method of swapping battery in an electric vehicle.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0007] FIG. **1** illustrates a control unit **13** in an electric vehicle **12** according to one embodiment of the invention. The control unit **13** adapted to sense a battery voltage level in an electric vehicle **12**, when the electric vehicle **12** is in a functional mode and to determine a distance that the electric vehicle **12** could travel based on the sensed battery voltage level. The control unit **13** adapted to detect at least one battery-swapping center **16** in a predefined distance, when the battery voltage level is below a threshold value and to update at least one battery-swapping center **16** regarding the detected battery voltage level of the electric vehicle **12** for swap of a battery **14** of the electric vehicle **12**.

[0008] Further the construction of a system **10** comprising the control unit **13** and the components of the system **10** is explained as follows. The control unit **13** adapted to determine an optimal operating point during the swapping of the battery **14** of the electric vehicle **12**. The optimal operating point is a point where, the control unit **13** uses a maximum power of the electric vehicle battery **14** to cover/travel a maximum distance, when the electric vehicle **12** is in functional mode. The operating point is also a point where, at least one battery-swapping center **16** detects the request from the vehicle prior for swapping of the battery **14**. At the operating point, the battery-swapping center **16** will have maximum requests from the electric vehicle **12** for multiple battery swaps. At least one characteristic of at least one battery-swapping center **16** is altered to achieve the optimal operating point based on a request transmitted from the control unit **13**. The characteristics of the battery-swapping center **16** is chosen from a group of characteristics comprising optimal supply of fully charged batteries **20**, capacity of the battery swapping center **16** to charge the battery **14** of the electric vehicle **12**, cost of at least one battery swapping method or the like.

[0009] According to one embodiment of the invention, the system **10** comprises a cloud server/database **18** connected via a communication means, between at least one electric vehicle **12** and to multiple battery swapping centers **16**, where the vehicle is traveling. The communication means is a wireless network like a Wi-Fi.

[0010] FIG. **2** illustrates a flow chart of a method of swapping a battery **14** in an electric vehicle **12**. In step S**1**, a battery voltage level in the electric vehicle **12** is sensed, when the electric vehicle **12** is in a functional mode. In step S**2**, a distance is determined that the electric vehicle **12** could travel based or, the sensed battery voltage level. In step S**3**, at least one battery-swapping center **16** in a predefined distance is detected, when the battery voltage level is below a threshold value. In step S**4**, at least one battery-swapping center **16** is upgraded regarding the detected battery voltage level of the electric vehicle **12** for swap of a battery **14** of the electric vehicle **12**.

[0011] The method of swapping a battery **14** in an electric vehicle **12** is explained in detail. The user of the electric vehicle **12** inputs an origin and a destination information into the vehicle **12**. Based on the battery voltage level present in the electric vehicle **12**, the control unit **13** determines the maximum distance that can be covered when the vehicle **12** is in operational mode. When the vehicle **12** starts the trip from the origin to the destination, the control unit **13** detects multiple battery-swapping centres **16** in a predefined distance range from the current location of the vehicle **12**, upon detecting a minimum battery voltage in the battery of the vehicle **12**. According to one embodiment of the invention, the control unit **13** of the electric vehicle **12** directly establishes the communication with the control unit of at least one battery-swapping centre **16**. According to another embodiment of the invention, the control unit **13** transmits a request to the battery-swapping centres **16** via the cloud server **18**, for the swap of the battery or to charge the battery **14**. At least one battery-swapping centre **16**, upon detecting the request from the control unit **13** of the vehicle **12**, transmits/acknowledges the requirement based on the capacity of the batteries **20** available in the centre **16** or based on the availability to charge the battery **14** of the vehicle **12**. The characteristics of the battery-swapping centre **16** as mentioned above is transmitted to the control unit **13** of the vehicle **12**. Based on at least one characteristic of the battery-swapping centre **16**, the control unit **13** initiates the process of the battery swapping, before reaching the battery-swapping centre **16**.

[0012] The control unit **13** transmits the requirements comprising number of batteries **14** needed to be swapped, the time to charge the current batteries, cost of the batteries or the like. The control unit **17** present in at least one battery-swapping centre **16**, receives the request for swapping of the battery **14** from the electric vehicle **12** and responds accordingly. The control unit **13** of the electric vehicle **12** and the control unit **17** of the battery-swapping centre **16** responds to each other requests, in such a way that, the optimal operating point where, both the swapping-centres **16** and the electric vehicles **14**, will experience a maximum output in terms of efficiency. According to one embodiment of the invention, a learning technique like a multi-objective optimization technique (as known to a person skilled in the art) is applied to determine the optimal operating point.

[0013] With the above system **10** disclosed, determines the optimal operating regions for each participant (battery-swapping center **16** and the electric vehicle **14**) based on at least one objective functions while ensuring sustainability of the system **10**. For an individual vehicle, it determines the optimal choice of battery-swapping center **16** and swapping time in order to maximize distance per battery while ensuring continuous drive time. For an individual battery swapping station—efficient operation is through the maximum swap operations and minimum duration of charging and total charging load. The system **10** incorporates a multi-objective reinforcement-learning technique, which learns optimal configurations for each participant, for an individual battery-swapping center **16**, it determines the optimal batteries **20** to charge to ensure optimal supply of fully charged batteries **20**.

[0014] It should be understood that embodiments explained in the description above are only illustrative and do not limit the scope of this invention. Many such embodiments and other modifications and changes in the embodiment explained in the description are envisaged. The scope of the invention is only limited by the scope of the claims.

1. A method of achieving an optimal operation point for swapping a battery in an electric vehicle, comprising:

sensing a battery voltage level of the battery in the electric vehicle when the electric vehicle is in a functional mode;

determining a distance that the electric vehicle can travel based on the sensed battery voltage level;

detecting at least one battery swapping center in a predefined distance when the sensed battery voltage level is below a threshold value; and

transmitting to the at least one battery-swapping center information regarding the sensed battery voltage level for swap of the battery of the electric vehicle.

2. The method as claimed in claim **1**, further comprising:

determining an optimal operating point to regulate the swapping of the battery of the electric vehicle.

3. The method as claimed in claim **2**, further comprising:

utilizing a maximum voltage level of the battery voltage in the electric vehicle at the optimal operating point to cover a maximum distance when the electric vehicle is in the functional mode.

4. The method as claimed in claim **1**, further comprising:

transmitting a request from the electric vehicle; and

receiving information regarding at least one characteristic of the detected at least one battery swapping center upon the transmission of the request.

5. The method as claimed claim **4**, wherein the at least one characteristic of the at least one battery swapping center includes an optimal supply of fully charged batteries, a capacity of the battery swapping center to charge the battery of the electric vehicle, a cost of at least one battery swapping, or the like.

6. A control unit in an electric vehicle, comprising:

a communications device,

the control unit configured to:

sense a battery voltage level of a battery in an electric vehicle, when the electric vehicle is in a functional mode;

determine a distance that the electric vehicle can travel based on the sensed battery voltage level;

detect at least one battery swapping center in a predefined distance when the sensed battery voltage level is below a threshold valve; and

transmitting, using the communications device, to the at least one battery-swapping center information regarding the sensed battery voltage level for swap of the battery (**14**) of the electric vehicle.

7. The control unit as claimed in claim **6**, wherein the control unit is further configured to:

determine an optimal operating point during the swapping of the battery of the electric vehicle.

8. The control unit as claimed in claim **7**, wherein the control unit is further configured to:

transmit a request from the electrical vehicle;

receive information regarding a characteristic of the detected at least one battery swapping center upon the transmission of the request; and

alter the characteristic of the detected at least one battery-swapping center to achieve the optimal operating point.

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