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## SYSTEM AND METHOD FOR ELECTRIC VEHICLE CHARGING CONTROL MANAGEMENT


### Abstract

Systems and methods are disclosed herein for managing electric vehicle charging control that provide the reduction of the operational cost to charge an electric vehicle by an energy provider and the reduction of load power consumption. In some examples, a charging control unit can include at least one processor, at least one memory, and an energy cost program stored in the memory to provide calculations for one or more optimized charging windows based on the operational cost of providing electricity by the energy provider. The energy cost information can be acquired by performing a day-ahead web scrape of a publicly available energy cost aggregator for the day-ahead settlement point cost of electricity and the market price of electricity. The charging control unit can provide charge control commands to the EV via a vehicle application programming interface.



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## Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates to systems and methods for electric vehicle charging control management.

BACKGROUND

[0002] Electric vehicle (EV) charging can have a large contribution to peak power consumption to a power grid with regards to energy management control. The adoption of renewable energy control strategies rely on accurate system dynamics to be available to a smart grid. Energy management is a core issue for the smart grid and can be beneficial for both the customers and energy providers. The main challenges come from uncertainties on both the power-supply and power-demand sides. EV charging has become one of the major power demands for the residential sector with the fast increase of EV adoption.

SUMMARY

[0003] The present disclosure relates to systems and methods for electric vehicle charging control management.

[0004] In an example, a system for charging an electric vehicle can include one or more processors. The system for charging the electric vehicle can include a memory. The system for charging the electric vehicle can include one or more programs, wherein the one or more programs are stored in the memory and can include instructions to be executed by the one or more processors. The instructions for charging an electric vehicle can include receiving user preference information from a user via a mobile communication device. The instructions for charging an electric vehicle can include processing a web request to retrieve energy cost information from an energy cost aggregator. The instructions for charging an electric vehicle can include calling a vehicle application programming interface (API) to retrieve telemetry information of the electric vehicle at a charging station. The instructions for charging an electric vehicle can include determining a state of charge (SoC) of the electric vehicle based on the telemetry information. The instructions for charging an electric vehicle can include determining at least one time window to charge the electric vehicle based on the energy cost aggregator. The instructions for charging an electric vehicle can include providing a charge control signal to the electric vehicle in electrical communication with the charging station to charge the electric vehicle based on the SoC of the electric vehicle, the user preference information, and the determined at least one time window.

[0005] In yet another example, a method of charging an electric vehicle can include employing at least one processor executing computer executable instructions stored on at least one non-transitory computer readable medium to perform operations. The operations can include receiving, by the processor, user preference information from a user via a mobile communication device. The operations can include processing, by the processor, a web request to retrieve energy cost information from an energy cost aggregator. The operations can include calling, by the processor, a vehicle application programming interface (API) to retrieve telemetry information of the electric vehicle at charging station. The operations can include determining, by the processor, a state of charge (SoC) of the electric vehicle based on the telemetry information. The operations can include determining, by the processor, at least one time window to charge the electric vehicle based on the energy cost aggregator. The operations can include providing, by the processor, a charge control signal to the electric vehicle in electrical communication with the charging station to charge the electric vehicle based on the SoC of the electric vehicle, the user preference information, and the determined at least one time window.

## Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0006] FIG. **1** illustrates a diagram of a system for electric vehicle charging control management.
[0007] FIG. **2** is an example of a flow chart for a charging optimization model of vehicle telemetry.
[0008] FIG. **3** is an example of an optimized charging schedule.
[0009] FIG. **4** is an example of a flow diagram for electric vehicle charging control management.
DETAILED DESCRIPTION
[0010] The present disclosure relates to systems and methods for electric vehicle charging control management. As described herein, the electric vehicle (EV) charging control management system is of particular significance with respect to the reduction of the operational cost to provide electric energy by an energy provider and the reduction of load power consumption to charge an electric vehicle. As described herein, the configuration of the EV charging control management system provides improvements against EV charge scheduling based on the consumer price of electricity.
[0011] As an example, the EV charging control management system described herein includes one or more processors executing instructions to perform an operation of scheduling the charging of an EV. In one example, a charging control unit can include at least one processor, at least one memory, and an energy cost program stored in the memory to provide calculations for one or more optimized charging windows based on the operational cost of providing electricity by the energy provider (e.g., a utility company, a retail energy provider, etc.) The energy cost information can be acquired by performing a day-ahead web scrape of a publicly available energy cost aggregator for the day-ahead settlement point cost of electricity and the market price of electricity. The charging control unit can provide charge control commands to the EV via a vehicle application programming interface (API). Based on a charging optimization model of vehicle telemetry acquired from the EV via the vehicle API, the charging control unit can communicate to the EV, via the vehicle API, the optimal time of day to draw electric energy from a home charging station.
[0012] In an example, an EV user can provide preferences (e.g., minimum state of charge (SoC), maximum SoC, departure time, etc.) via a mobile device. The user preference information can be acquired from the user via a customer API employed by the charging control unit. In one example, additional customer information (e.g., customer premises coordinates, customer premises grid zone, etc.) can be acquired via the customer API in communication with an energy provider server.
[0013] In an example, the charging control unit can compile inputs (e.g., current SoC, current plugged in status, current coordinates, customer min/max preferences, customer departure time, Time-Of-Use (TOU) rate, day ahead settlement price in customer zone, historical EV charge rate, etc.) to output one or more optimized charging windows and charge control commands to facilitate charging an EV. In one example, the charging control unit can store EV authentication tokens for communicating charge control commands to the EV.
[0014] Referring to FIG. **1**, a block diagram of a system for electric vehicle charging control management **100** is depicted. The system includes a charging control unit **102** configured to compile inputs, to calculate one or more optimized windows for charging an EV **104**, and to provide a charging signal to the EV **104** during the one or more optimized windows for charging. The charging control unit includes a processor **106**, a memory **108**, and a energy cost program **110** that can provide instructions for the optimized charging of the EV **104**.
[0015] The system for electric vehicle charging control management **100** can be configured to determine one or more optimized charging windows by gathering energy cost information from an energy cost aggregator **112**. The energy cost aggregator **112** can be a website or other program

containing energy cost information (e.g., day ahead settlement price in customer zone, etc.). The charging control unit **102** can be configured to process a web request to retrieve the energy cost information from the energy cost aggregator **112** for information on day ahead analysis of the cost for providing electric energy. The charging control unit **102** can be configured to generate a schedule based on the day ahead cost for providing electric energy to reduce the cost of charging the EV **104** for the energy provider.

[0016] In one example, the charging control unit **102** can employ a customer API **114** to obtain information pertaining to the energy customer. The customer API **114** can be in communication with an energy provider server **116** to obtain customer information (e.g., customer premises coordinates, customer premises load zone, customer utility TOU rate, etc.). The customer information can be provided to the charging control unit **102** via the customer API **114**. The charging control unit **102** can be configured to utilize the customer information to determine one or more optimal charging windows to charge the EV **104** by determining the load zone and the cost of providing energy to the load zone, whereas the energy customer can charge the EV **104** at the home charging station **118** therein.

[0017] In an example, the energy customer can input user preference information (e.g., minimum SoC, maximum SoC, departure time, etc.) into a mobile device **120**. The charging control unit **102** can employ the customer API **114** to retrieve the user preference information from the mobile device **118**. In another example, the charging control unit **102** can be configured to utilize the user preference information to generate one or more optimized charging windows to charge the EV **104**. In one example, the mobile device **120** can include an application that allows the energy customer to adjust the user preference information. The energy customer can utilize the application to grant permission to the charging control unit **102** to utilize data pertaining to the EV **104**.

[0018] In an example, the charging control unit **102** can employ a vehicle API **122** to obtain telemetry information (e.g., current SoC, current plugged in status, current EV location, historical EV charge rate, etc.) from the EV **104**. The telemetry information obtained from the EV **104** can be communicated to the charging control unit **102** by the vehicle API **122** to be utilized in a charging optimization model, as described in FIG. **2** below, that can be processed by the charging control unit **102**. In one example, when the EV **104** is plugged into the home charging station **118**, the EV can transmit telemetry information periodically (e.g., every minute) via the vehicle API **122** back to the charging control unit **102** for charging commands to be issued until the EV **104** is fully charged or the user preferences are met by the time of the next departure.

[0019] In an example, a charging control program **124** can be stored in a memory (not shown) on a unit comprising a processor (not shown) other than the memory and processor of the charging control unit **102**. In one example, the unit comprising the charging control program **124** can be run from a different geographic location than the charging control unit **102**, whereby the charging control unit **102** and the unit comprising the charging control program **124** can be communicatively coupled via the world wide web. The charging control program **124** can be configured to receive the outputs of the charging control unit **102** via the vehicle API **122**. Based on the charging optimization model and the charging schedule generated by the charging control unit **102**, the charging control program **124**, can issue a charge on or charge off signal via the vehicle API **122** to the EV **104**. Upon receiving the charge signal, the EV **104**, in electrical communication with the home charging station **118**, can begin to attain a charge until the user preferences are satisfied or until a full charge is attained. In one example, the charging control program can be configured to issue the required mode (e.g., fast charge, etc.) to satisfy the necessary charge of the EV **104** based on the outputs of the charging control unit **102** and the user preference information.

[0020] In an example, the energy customer can set the user preferences via the mobile device **120** to a minimum SoC. Once the system detects that the EV **104** has been plugged in having a current SoC of less than the minimum SoC, the charging control program **124** can be configured to immediately issue a charge signal to reach the minimum SoC set by the energy customer. In one example, the charging control program **124** can stop the EV **104** from charging past the minimum SoC until an optimized charging window has been reached as determined by the charging control unit **102**, whereby the charging control program **124** can issue another charge signal to charge the EV up to the maximum SoC as set by the energy customer or until a full charge is reached.

[0021] In another example, the energy customer can set the user preference via the mobile device **120** to a maximum SoC. Once the system detects that the EV **104** is charging and has met the maximum SoC, the charging control program can issue a charge off signal, based on the user preferences. The vehicle API **122** can periodically communicate the current SoC to the charging control unit **102**. The current SoC can be communicated to the mobile device **120** via the customer API **114**.

[0022] The vehicle API **122** can be configured to communicate telemetry information (e.g., battery level, battery range, battery capacity, etc.) of the EV **104** back to the charging control unit **102** during the charge of the EV **104** or while the EV **104** is away from the home charging station **118**. The telemetry information can include values that factor into the charging optimization model. In an example, the charging control unit **102** can make determinations based on the telemetry information and communicate the determinations to the charging control program **124** which issues the charge signal to the EV **104** via the vehicle API **122** based on the determinations of the charging control unit **102**.

[0023] In an example, the charging control unit **102** can be configured to prioritize the minimization of operational costs of the energy provider and the power being drawn to charge the EV **104** in a load zone. The charging control unit **102** generates the charging schedule for the EV **104** based on the energy cost information by the hour for the day ahead. The charging control unit **102** can generate a plurality of charging windows based on the user preferences entered via the mobile device **120** and other contributing factors. However, the charging control unit **102** can be configured to generate an optimized charging window which places priority on reducing the cost of delivering the electricity to charge the EV **104**.

[0024] In one example, the charging control unit **102** can periodically issue telemetry checks via the vehicle API **122** to retrieve telemetry information regarding the EV **104**. In another example, the EV **104** can communicate with the charging control unit **102** via the vehicle API **122** immediately upon being plugged in to the home charging station **118**. Once the EV **104** is plugged in to the home charging station **118**, the charging control unit **102** can be configured to begin the charging optimization model to determine the logic for charging the EV **104**.

[0025] In an example, the charging control unit **102** can be configured to determine the charge rate based on the historical at-home charging sessions. In one example, the historical at-home charging sessions can be retrieved from the EV **104** and communicated to the charging control unit **102** via the vehicle API **122**. In another example, the historical at-home charging sessions can be retrieved from the charging control program **124** and communicated to the charging control unit **102** via the vehicle API **122**.

[0026] In an example, the charging control program **124** can periodically check with the charging control unit **102** via the vehicle API **122** to determine whether it is time to issue a charge control signal to the EV **104**. The charging control unit **102** can communicate to the charging control program **124** via the vehicle API **122** to hold a no charge signal until a command is issued to send a charge on signal to the EV **104** by the charging control unit **102**.

[0027] Turning now to FIG. **2**, a flow chart for a charging optimization model of vehicle telemetry **200** is depicted. The charging optimization model of vehicle telemetry **200** can be logical instructions performed by the system for electric vehicle charging control management **100**, as described in FIG. **1** above. In one example, the logical instructions of the charging optimization model of vehicle telemetry **200** can be performed by one or more processors. In another example, each processor can be at a different geographical location than the EV **104** that is being charged.

[0028] At **202**, a telemetry check can be performed to remotely monitor electrical parameters of the

EV **104** in real-time. In an example, telemetry information of the EV **104** can be wirelessly broadcast from the EV **104** to the charging control unit **102** via the vehicle API **122**, as described above in FIG. **1**. The vehicle API **122** can retrieve telemetry information (e.g., current SoC, current plugged in status, current coordinates, historical EV charge rate, etc.) In one example, the telemetry check can be performed periodically to determine the status of the EV **104** to be charged. The telemetry information gathered from the telemetry check can be used to generate one or more optimized charging windows by the charging control unit **102** based on the charge state of the EV **104** and the user preferences entered by the energy customer via the mobile device **120**.

[0029] At **204**, the vehicle API **122** can determine whether the EV **104** is plugged into a charging station. In an example, the vehicle API **122** can determine whether the EV **104** is plugged into a charging station. If it is determined by the vehicle API **122** that the EV **104** is plugged into a commercial charging station, no changes are necessary to be made and the EV **104** can continue its charge. In one example, when it is determined by the vehicle API **122** that the EV **104** is plugged into a commercial charging station within the same load zone as the home charging station **118**, the system **100**, as described above in FIG. **1**, can be configured to perform the charging operations of the EV **104** whereby the commercial charging station can charge the vehicle based on the operational cost of providing electricity by the energy provider and/or to reduce the load of charging the EV **104** in the load zone. The charging control unit **102** can thereby be configured to adjust the charging mode (e.g., fast charging, etc.) of the EV **104**.

[0030] At **206**, the charging control unit **102** can determine whether the EV **104** has been plugged into the home charging station **118** as defined by the customer information retrieved from the energy provider server **116** via the customer API **114**. In an example, the vehicle API **122** can be configured to locate, via a suitable tracking system (e.g., global positioning system, mobile network, etc.), the geographical coordinates of the EV **104**. Thereby, the charging control unit **102** can be configured to verify the arrival of the EV **104** at the home charging station **118** by matching the telemetry information of the vehicle API **122** with the customer premises of the customer information as retrieved by the customer API **114**. Upon determining by the charging control unit **102** that the EV **104** is not plugged into the home charging station **118**, no change is necessary to be made. Upon determining that the EV **104** is plugged into the home charging station **118**, the charging control unit **102** can evaluate the telemetry information to determine whether the parameters have been met to charge the EV **104** within one or more optimized charging windows.

[0031] At **208**, once it has been determined by the vehicle API **122** that the EV **104** is currently plugged into the home charging station **118**, the charging control unit **102** can determine whether the current SoC of the EV **104** is greater than or equal to the minimum SoC as set by the energy customer via the mobile device **120**. In an example, once it is determined that the EV **104** has a current SoC that is less than the minimum SoC as set via the mobile device **120**, the charging control unit **102** can be configured to cause the charging control program **124** to issue a charge on signal until the EV **104** has reached the minimum SoC. In one example, the EV **104** can be provided a charged on signal by the charging control program **124** outside of the one or more optimized charging windows to obtain the minimum SoC to maintain an operational state of the EV **104**.

[0032] At **210**, the vehicle API **122** can determine whether the EV **104** has a current SoC that is less than or equal to the maximum SoC as set by the energy customer via the mobile device **120**. In one example, the EV **104** can be plugged in to the home charging station **118**, whereby the vehicle API **122** can determine that the EV **104** has a current SoC greater than the maximum SoC setting. Thereby, the charging control program **124** can send a charge off signal to the EV **104**. In another example, the EV **104** can be plugged in to the home charging station **118**, whereby the vehicle API **122** can determine that the EV **104** has a current SoC less than the maximum SoC setting. The vehicle API **122** can communicate the telemetry information to the charging control unit **102** to determine whether the EV **104** has satisfied the parameters to be issued a charge on signal.

[0033] At **212**, the charging control unit **102** can be configured to receive telemetry information (e.g., historical EV charge rate) from the EV **104** via the vehicle API **122**. The charging control unit **102** can be configured to utilize the historical EV charge rate of the EV **104** and determine a suitable charge rate considering the energy cost information and the current load of electricity in the load zone. In an example, the charging control unit **102** can determine the historical at-home charge rate of the EV **104** by isolating the charging sessions that occur at the home charging station **118**. In another example, the charging control unit can isolate the charging sessions of the EV **104** to charging sessions that occurred within the same load zone of the home charging station **118** to evaluate the charge rate based on the electricity usage within the load zone.
[0034] At **214**, the charging control unit **102** can be configured to evaluate the time needed to charge the EV to the maximum SoC, based on the user preference information as set by the energy customer via the mobile device **120**. In an example, the charging control unit **102** can reevaluate the time needed to charge the vehicle to a maximum SoC, based on a change in the charging mode (e.g., fast charging) which can be triggered by a change in the electrical load on the load zone. In another example, the charging control unit **102** can change the charging mode to achieve the determined time needed to charge the EV **104** to the maximum SoC.
[0035] At **216**, the charging control unit **102** can determine whether the EV **104** has a current SoC that is less than the maximum SoC. In an example, the charging control unit **102** has determined that the time to charge the EV **104** is not less than the time until departure, whereby the charging control unit **102** can instruct the charging control program **124** to issue a charge on signal to the EV **104** to provide a continuous charge towards the maximum SoC by the scheduled departure time. In another example, the charging control unit **102** has determined that the time to charge is less than the time to departure, whereby the charging control unit **102** can be configured to gather additional telemetry information for the EV **104** via the vehicle API **122**. In one example, the charging control unit **102** can be configured to check the status of the electricity supplied to the load zone, whereby the customer API **114** can be called to perform a status check of the load zone from the energy provider server **116** to determine whether an adjustment can be made to the charging mode of the EV **104** to decrease the time to charge the EV **104**.
[0036] At **218**, the charging control unit **102** can be configured to generate a data table comprising an optimized charging schedule consisting of one or more optimized charging windows. In one example, the optimized charging window of the optimized charging schedule can be based on the periods throughout the day in which the lowest cost for providing electric energy to the energy customer can be achieved by the energy provider. In an example, the one or more optimized charging windows can be generated by scraping the energy cost aggregator **112** website for day ahead energy service costs to the energy provider. Generating the optimized charging window will be discussed in further detail below in FIG. **3**. In one example, the one or more charging windows can be generated periodically (e.g., daily) to determine the most cost efficient time to charge the EV **104** for the following day.
[0037] At **220**, the charging control unit **102** can be configured to determine whether it is time to charge the EV **104** based on the optimized charging schedule. In one example, the charging control unit **102** can determine that the present hour is an hour that the generated optimized charging schedule has determined to be outside of the optimized charging window, whereby the charging control program **124** can send a charge off signal to the EV **104**. In another example, the charging control unit **102** can be configured to identify that the present hour falls within an optimized charging window of the optimized charging schedule, whereby the charging control program **124** can send a charge on signal to the EV **104**. In one example, the EV **104** can communicate to the home charging station **118** to supply electrical energy to charge the battery of the EV **104**.
[0038] Turning now to FIG. **3**, an example of an optimized charging schedule **300** is depicted. In one example, data obtained from the energy cost aggregator **112** can be compiled in an hourly breakdown of economic details with regards to the cost and price of energy provided in a load zone

of the electric grid. In an example, the charging control unit **102** can be configured to extract raw data from the energy cost aggregator **112** in a web scraping operation. In another example, the charging control unit **102** can utilize the raw data extracted from the energy cost aggregator **112** to generate a data table of day ahead energy market information, whereby a charging signal can be appended to each record of the data table to determine the optimal hours to charge the EV **104**.

[0039] In an example, the optimized charging schedule **300** can utilize an identifier field (e.g., an integer) for each record representing a period of the day that electric energy can be supplied to an energy customer by an energy provider for charging the EV **104**. In one example, an electric energy cost field (not shown) can be appended to each record of the optimized charging schedule **300** to indicate the cost of providing the energy to the energy customer. In an example, the first record of the optimized charging schedule **300** can indicate the period of the day in which rush hour traffic often begins, whereby the departure time as set by the energy customer via the mobile device **120** most often occurs. In another example, the EV **104** can be expected to return to the home charging station **118** around the 1600 hour, whereby the optimized charging schedule populates a charge signal to records indicating periods when the EV **104** can be likely to be present.

[0040] In an example, the charging control unit **102** can identify at least one optimized charging window based on the hours of the day within which optimized charging of the EV **104** can occur. In one example, the charging control unit **102** can obtain a time-of-use rate that can be a price adjustment based on the time of day that aligns with electrical grid demands. The change in the time-of-use rate can provide an indication to the charging control unit **102** that an optimized charging window can begin upon the decrease of the time-of-use rate, whereby ending upon the increase of the time of use rate. In one example, the charging control unit **102** can identify that the optimized charging window will last for 8 hours, whereby the charging control unit **102** can utilize this information to determine that there is enough time to charge the EV **104** to the maximum SoC as set by the energy customer via the mobile device **120**.

[0041] For the sake of brevity, a market price is provided in the optimized charging schedule **300** due to the number of suppliers and the variability of the cost of providing the electric energy. In one example, the charging control unit **102** can generate a day-ahead optimized charging schedule for each supplier available to the energy provider. In an example, the charging control unit **102** can be configured to identify a batch of continuous records within the optimized charging window representative of hours needed to charge the EV **104** to the maximum SoC based on the lowest cost of providing the electric energy to the energy customer. By identifying the lowest cost of providing the electric energy to the energy customer within an optimized charging window, the energy provider can provide an enhanced account for the environmental effect of the system for electric vehicle charging control management **100**.

[0042] In an example, as stated above, the charging control unit **102** can be configured to append a charge signal (e.g., charge on, charge off) to a record of the optimized charging schedule **300** at an hour that the EV **104** can be expected to be in the presence of the home charging station. In one example, the charging control unit **102** can assign a charge off signal to a record comprising hours of the day that do not occur within an optimized charging window and records that do not comprise the lowest cost available for providing the electric energy to the energy customer for charging the EV **104** that do occur within the optimized charging window. In another example, the charging control unit **102** can assign a charge on signal to a record comprising hours of the day that include the lowest cost available for providing the electric energy to the energy customer for charging the EV **104**. The charge signal provided in the optimized charging schedule **300** can be utilized to instruct the charging control program **124** to communicate with the EV **104** to begin an optimized charging session.

[0043] The foregoing outlines features of several examples so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the examples introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they make various changes, substitutions, alterations herein without departing from the spirit and scope of the present disclosure.

[0044] Referring now to the example of FIG. **4**, illustrated is a flow diagram **400** for charging an electric vehicle in accordance with one or more examples described herein.

[0045] At **402**, the flow diagram comprising receiving user preference information from a user via a mobile communication device.

[0046] At **404**, the flow diagram comprises processing a web request to retrieve energy cost information from an energy cost aggregator.

[0047] At **406**, the flow diagram comprises calling a vehicle application programming interface (API) to retrieve telemetry information of the electric vehicle at a charging station.

[0048] At **408**, the flow diagram comprises determining a state of charge (SoC) of the electric vehicle based on the telemetry information.

[0049] At **410**, the flow diagram comprises determining at least one time window to charge the electric vehicle based on the energy cost aggregator.

[0050] At **412**, the flow diagram comprises providing a charge control signal to the electric vehicle in electrical communication with the charging station to charge the electric vehicle based on the SoC of the electric vehicle, the user preference information, and the determined at least one time window.

[0051] The charging of the electric vehicle further includes calling a customer API to retrieve customer information for the user from an energy provider server.

[0052] The charging of the electric vehicle further includes determining the electric vehicle is connected to the charging station at a home location of the user based on the customer information retrieved from the energy provider server.

[0053] The charging of the electric vehicle further includes utilizing the customer information to determine a geographic load zone, wherein the cost of providing energy is based on the geographic load zone.

[0054] The charging of the electric vehicle further includes generating an optimized charging schedule, wherein the at least one time window to charge the electric vehicle is configured based on the cost of providing energy in the geographic load zone.

[0055] The charging of the electric vehicle further includes providing a charging control signal to the electric vehicle within the at least one time window, wherein a charge on signal occurs in a lowest energy cost window, and wherein a charge off signal occurs outside of the lowest energy cost window.

[0056] The charging of the electric vehicle further includes calculating a vehicle charge rate based on historical at-home charging sessions.

[0057] The charging of the electric vehicle further includes evaluating a period of time to charge the electric vehicle to a maximum SoC based on the user preference information.

[0058] The charging of the electric vehicle further includes determining that the period of time to charge the electric vehicle to the maximum SoC is less than or equal to the time until the electric vehicle is scheduled to depart a home location based on the user preference information.

[0059] The charging of the electric vehicle further includes providing a charge on signal to the electric vehicle to obtain a minimum SoC of the electric vehicle upon arriving at a home location.

[0060] The above description includes non-limiting aspects of the various examples. It is, of course, not possible to describe every conceivable combination of components or methods for purposes of describing the disclosed subject matter, and one skilled in the art may recognize that further combinations and permutations of various examples are possible. The disclosed subject matter is intended to embrace all such alterations, modifications, and variations that fall within the spirit of the appended claims.

[0061] With regard to the various functions performed by the above described components, the terms (including a reference to a "means") used to describe such components are intended to also include, unless otherwise indicated, any structure(s) which performs the specified function of the described component (e.g., functional equivalent), even if not structurally equivalent to the disclosed structure. In addition, while a particular feature of the disclosed subject matter may have been disclosed with respect to only one of several implementations, such a feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

[0062] The terms "exemplary" and/or "demonstrative" as used herein are intended to mean serving as an example, instance, or illustration. For the avoidance of doubt, the subject matter disclosed herein is not limited to such examples. In addition, any aspect or design described herein as "exemplary" and/or "demonstrative" is not necessarily to be construed as preferred or advantageous over the other aspects or designs, nor is it meant to preclude equivalent structures and techniques known to one skilled in the art. Furthermore, to the extent that the terms "includes," "has," "contains," and other similar words are used in either the detailed description or the claims, such terms are intended to be inclusive—in a manner similar to the term "comprising" as an open transition word—without precluding any additional or other elements.

[0063] The description of illustrated examples of the subject disclosure as provided herein, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed examples to the precise forms disclosed. While specific examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such examples, as one skilled in the art can recognize. In this regard, while the subject matter has been described herein in connection with various examples and corresponding drawings, where applicable, it is to be understood that other similar examples can be used or modifications and additions can be made to the described examples for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single example described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

## Claims

**1**. A system for charging an electric vehicle, comprising: one or more processors; a memory; and one or more programs, wherein the one or more programs are stored in the memory and configured to be executed by the one or more processors, the one or more programs including instructions for: receiving user preference information from a user via a mobile communication device; processing a web request to retrieve energy cost information from an energy cost aggregator; calling a vehicle application programming interface (API) to retrieve telemetry information of the electric vehicle at a charging station; determining a state of charge (SoC) of the electric vehicle based on the telemetry information; determining at least one time window to charge the electric vehicle based on the energy cost aggregator; and providing a charge control signal to the electric vehicle in electrical communication with the charging station to charge the electric vehicle based on the SoC of the electric vehicle, the user preference information, and the determined at least one time window.

**2**. The system of claim 1, wherein the instructions include calling a customer API to retrieve customer information for the user from an energy provider server.

**3**. The system of claim 2, wherein the one or more programs include determining the electric vehicle is connected to the charging station at a home location of the user based on the customer information retrieved from the energy provider server.

**4**. The system of claim 3, wherein the instructions include utilizing the customer information to determine a geographic load zone, wherein the cost of providing energy is based on the geographic load zone.

**5**. The system of claim 4, wherein the instructions include generating an optimized charging schedule, wherein the at least one time window to charge the electric vehicle is configured based on the cost of providing energy in the geographic load zone.

**6**. The system of claim 5, wherein the instructions include providing a charging control signal to the electric vehicle within the at least one time window, wherein a charge on signal occurs in a lowest energy cost window, and wherein a charge off signal occurs outside of the lowest energy cost window.

**7**. The system of claim 1, wherein the instructions include calculating a vehicle charge rate based on historical at-home charging sessions.

**8**. The system of claim 1, wherein the instructions include evaluating a period of time to charge the electric vehicle to a maximum SoC based on the user preference information.

**9**. The system of claim 8, wherein the instructions include determining that the period of time to charge the electric vehicle to the maximum SoC is less than or equal to the time until the electric vehicle is scheduled to depart a home location based on the user preference information.

**10**. The system of claim 1, wherein the instructions include providing a charge on signal to the electric vehicle to obtain a minimum SoC of the electric vehicle upon arriving at a home location.

**11**. A method of charging an electric vehicle, comprising: employing at least one processor executing computer executable instructions stored on at least one non-transitory computer readable medium to perform operations comprising: receiving user preference information from a user via a mobile communication device; processing a web request to retrieve energy cost information from an energy cost aggregator; calling a vehicle application programming interface (API) to retrieve telemetry information of the electric vehicle at a charging station; determining a state of charge (SoC) of the electric vehicle based on the telemetry information; determining at least one time window to charge the electric vehicle based on the energy cost aggregator; and providing a charge control signal to the electric vehicle in electrical communication with the charging station to charge the electric vehicle based on the SoC of the electric vehicle, the user preference information, and the determined at least one time window.

**12**. The method of claim 11, further comprising: calling a customer API to retrieve customer information for the user from an energy provider server.

**13**. The method of claim 12, wherein the operations include determining the electric vehicle is connected to the charging station at a home location of the user based on the customer information retrieved from the energy provider server.

**14**. The method of claim 13, wherein the operations include utilizing the customer information to determine a geographic load zone, wherein the cost of providing energy is based on the geographic load zone.

**15**. The method of claim 14, wherein the operations include generating an optimized charging schedule, wherein the at least one time window to charge the electric vehicle is configured based on the cost of providing energy in the geographic load zone.

**16**. The method of claim 15, wherein the operations include providing a charging control signal to the electric vehicle within the at least one time window, wherein a charge on signal occurs in a lowest energy cost window, and wherein a charge off signal occurs outside of the lowest energy cost window.

**17**. The method of claim 11, further comprising: calculating a vehicle charge rate based on historical at-home charging sessions.

**18**. The method of claim 11, further comprising: evaluating a period of time to charge the electric vehicle to a maximum SoC based on the user preference information.

**19**. The method of claim 18, wherein the operations include determining that the period of time to charge the electric vehicle to the maximum SoC is less than or equal to the time until the electric vehicle is scheduled to depart a home location based on the user preference information.

**20**. The method of claim 11, further comprising: providing a charge on signal to the electric vehicle to obtain a minimum SoC of the electric vehicle upon arriving at a home location.