TITLE OF THE INVENTION

POWER CONTROL NETWORK SYSTEM, CONTROL DEVICE AND CONTROL PROGRAM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The disclosures herein generally relate to a technique of controlling electric power supply.

2. Description of the Related Art

Smart grids have been proposed as transmission networks that can control flows of electric power from both of supply side and consumption side, and optimize the flows (See, for example, Patent Documents 1 to 4).

FIG. 1A and FIG. 1B schematically illustrate control in a conventional smart grid. In FIG. 1A, a control server (central server) controls a power plant, solar panels, an EV (Electric Vehicle), an air conditioner or the like in the predetermined region to be managed so that power generation amount (supply quantity) and consumption amount (quantity demanded) are simultaneously provided and the same quality.

As illustrated in FIG. 1B, the smart grid has an existence just like a pool, i.e. a water level of the pool rises when the power generation amount becomes greater, and the water level or the pool is lowered when the consumption amount becomes greater. Here, the water level of the pool is equivalent to an electric voltage or a frequency.

[Citation List]

[Patent Literature]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2011-36118
[PTL 2] Japanese Translation of PCT International Application Publication No. JP-T-2011-523545
[PTL 3] Japanese Translation of PCT International Application Publication No. JP-T-2013-539337
[PTL 4] Japanese Unexamined Patent Application Publication No. 2014-18059

SUMMARY OF THE INVENTION

[Technical Problem]

The control server illustrated in FIG. 1A controls total amount of power generation and power consumption. On this occasion, a power-generating facility (electric power source), a cost of which is the lowest, and which is close to the location of the power consumption, among required power generation sources, is desired to be ON from a standpoint of efficiency. When long distance transmission from an electric power source with a low level of power generation is performed, electric power loss may occur due to the long distance transmission.

However, in order to perform such control, it is necessary to know at which position (location) and how long each power consumption is to be performed, and furthermore, also on the power generation side, at which location, how much and how long power supply is possible, and to perform centralized control. Therefore, communication for control becomes enormous, and the control becomes too complicated. Then, realization becomes difficult. At present, the control can be maintained only of the total amount.

The present invention has been proposed in view of the above-described conventional problems, and aims at providing a mechanism that can supply electric power dispersively for respective electric power consumptions.

[Means to solve the Problem]

In order to solve the above-described problem, in the present invention, in a power control network system, a plurality of electric power supply sources and a plurality of electric power consumption sources are coupled via an electric power transmission network. The power control network system is provided with a control network overlaid on the electric power transmission network. A node corresponding to the electric power consumption source in the control network includes a query packet transmission circuit for sending a query packet requiring necessary electric power supply to a circumferential node, when electric power consumption is required in the node; a reply packet reception circuit for receiving a reply packet, which is a response to the query packet; and a consumption management circuit for selecting an electric power supply source that covers the electric power consumption requirement based on the received reply packet.

Effect of the invention

In the present invention, a mechanism that can supply electric power dispersively for the respective electric power consumptions can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[FIG. 1A]

FIG. 1 is a (first) diagram schematically depicting control in a conventional smart grid.

[FIG. 1B]

FIG. 1B is a (second) diagram schematically depicting the control in the conventional smart grid.

[FIG. 2]

FIG. 2 is a diagram depicting an example configuration of a system according to a first embodiment.

[FIG. 3]

FIG. 3 is a diagram depicting an example configuration of a HEMS controller.

[FIG. 4]

FIG. 4 is a flowchart depicting an example of a process according to the first embodiment.

[FIG. 5]

FIG. 5 is a diagram depicting an example of defining a range to which a query packet is sent by a number of hops.

[FIG. 6]

FIG. 6 is a diagram depicting an example of defining the range to which the query packet is sent by an IP address.

[FIG. 7]

FIG. 7 is a (first) diagram depicting an example of the query packet and a reply packet.

[FIG. 8]

FIG. 8 is a (second) diagram depicting an example of the query packet and the reply packet.

[FIG. 9]

FIG. 9 is a (third) diagram depicting an example of the query packet and the reply packet.

[FIG. 10]

FIG. 10 is a flowchart depicting an example of a process according to a second embodiment.

[FIG. 11]

FIG. 11 is a diagram depicting an example of an exchange query packet.

[FIG. 12]

FIG. 12 is a diagram depicting an example of determination of pair exchange.

[FIG. 13]

FIG. 13 is a diagram depicting an example configuration of a system according to a third embodiment.

[FIG. 14]

FIG. 14 is a flowchart depicting an example of a process according to the third embodiment.

[FIG. 15]

FIG. 15 is a diagram depicting an example configuration of a system according to a fourth embodiment.

[FIG. 16]

FIG. 16 is a diagram depicting an example of shuffle of a virtual network according to a fifth embodiment.

[FIG. 17]

FIG. 17 is a diagram depicting an example of a process according to a sixth embodiment.

[FIG. 18]

FIG. 18 is a diagram depicting an example of sending an exchange query according to the sixth embodiment.

[FIG. 19]

FIG. 19 is a flowchart depicting an example of a process according to a seventh embodiment.

[FIG. 20A]

FIG. 20A is a (first) diagram depicting an example of a priority curve.

[FIG. 20B]

FIG. 20B is a (second) diagram depicting an example of the priority curve.

[FIG. 20C]

FIG. 20C is a (third) diagram depicting an example of the priority curve.

[FIG. 21]

FIG. 21 is a flowchart depicting an example of a process according to an eighth embodiment.

[FIG. 22]

FIG. 22 is a diagram depicting an example of a change of the priority curve.

[FIG. 23]

FIG. 23 is a flowchart depicting an example of a process according to a ninth embodiment.

[FIG. 24]

FIG. 24 is a diagram depicting an example configuration of a system according to a tenth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, a preferred embodiment of the present invention will be described.

<First Embodiment>

FIG. 2 is a diagram depicting an example configuration of a system according to a first embodiment.

In FIG. 2, a control network 3 is configured in a form that overlays an electric distribution network 2 covering a plurality of homes 1A, 1B, 1C, …, and HEMS (Home Energy Management System) controllers 4A, 4B, 4C, … are provided as nodes corresponding to the homes 1A, 1B, 1C, …, respectively. The homes 1A, 1B, 1C, … include a home that is always an electric power consumption source, a home that is always an electric power supply source, and a home that is an electric power consumption source or an electric power supply source depending on a situation. Moreover, the homes 1A, 1B, 1C, … are not limited to individual homes, but may include business facilities of business operators that perform electric power generation.

FIG. 3 is a diagram depicting an example configuration of the HEMS controller 4 (4A, 4B, 4C, …).

In FIG. 3, the HEMS controller includes an information display unit 41, an information input unit 42, a consumption management unit 43, a supply management unit 44, and a packet transmission/reception unit 45.

The information display unit 41 has a function of displaying various pieces of information for a user. The information input unit 42 has a function of inputting various pieces of information from the user.

The consumption management unit 43 has a function of managing electric power consumption of an electric appliance in a home 1, in which the HEMS controller 4 is installed. In particular, when beginning to use or reserving for use of the electric

appliance is performed, transmission of a query packet searching for an electric power supply source that covers the demand for electric power is performed by the packet transmission/reception unit 45, and when a reply packet responding to the query packet is received, the electric power supply source is selected. Moreover, when the electric appliance responds to the reply packet, adjustment for start time of use or power consumption is performed.

The supply management unit 44 has a function of managing electric power supply (electric power selling), when an electric power facility is coupled to the HEMS controller 4 and the own node becomes an electric power supply source. Particularly, when receiving a query packet searching for an electric power supply source by the packet transmission/reception unit 45, a reply packet including an electric power cost or a distance index (information indicating a distance between an electric power consumption element and an electric power supply source) is sent by the packet transmission/reception unit 45.

The packet transmission/reception unit 45 has a function of sending/receiving various packets to/from a circumferential node.

FIG. 4 is a flowchart depicting an example of a process according to the first embodiment.

In FIG. 4, the consumption management unit 43 of the HEMS controller 4 on the consumption side waits for an occurrence of power consumption (including scheduled consumption) (step S101). When power consumption occurs (step S101: YES), information on required electric power, time of use,

or the like is acquired (step S102), and a query packet for requiring necessary electric power supply is sent in the form of a broadcast (step S103).

A HEMS controller 4 of the other circumferential node waits for reception of a query packet (step S104). When receiving the query packet (step S104: YES), the query packet is determined whether to have arrived within a predetermined range by a broadcast (step S105). When the query packet does not arrive within the predetermined range (step S105: NO), the query packet is forwarded to the other circumferential node (step S106).

FIG. 5 is a diagram depicting an example of defining the range to which the query packet is sent by a number of hops, and illustrates an example where the number of hops is "2". That is, when broadcasting a query packet from an electric power consumption source S, the query packet is sent up to the nodes A21, A22, A23, B21, C21, C22, D21 in which the number of hops reaches "2".

FIG. 6 is a diagram depicting an example of defining the range to which the query packet is sent by an IP address. In order to determine a higher adjacency relationship, IP addresses are assigned taking account of the structure of the electricity transmission grid from the electric power plant, and the range is determined based on the addresses. At a bifurcation portion of each electric distribution network, for example, an address divided to every 8 bits is assigned hierarchically. In this method, when the electric power consumption source S is, for example, "128.25.48.7", adjacent nodes are all nodes of "128.25.48.**". Moreover, nodes that are

separated by one more step" are in the node group of "128.25.**.**".

Returning to FIG. 4, the supply management unit 44 of the HEMS controller 4 acquires information on electric power that can be supplied at the own node, cost (electric power selling price), or the like (step S107), and determines whether to respond to a query packet (step S108). When the supply management unit 44 responds to the query packet (step S108: YES), a reply packet is returned (step S109).

The consumption management unit 43 of the HEMS controller 4, which has sent the query packet first, waits for reception of a reply packet (step S110). When receiving the reply packet (step S110: YES), the consumption management unit 43 determines whether to accept electric power based on the electric power cost and the distance index included in the reply packet (step S111). When receiving a plurality of replay packets, an optimum electric power supply source is selected from them.

When accepting the electric power (step S111: YES), the consumption management unit 43 sends an acceptance packet to a node of the electric power supply source (step S112), and records internally the electric power, the electric power cost, the electric power supply source, or the like (step S113).

The supply management unit 44 of the HEMS controller 4 of the other node waits for reception of a reply packet (step S114). When receiving the reply packet (step S114: YES), the supply management unit 44 records the electric power supply source, the electric power cost, the electric power consumption source, or the like (step S115).

FIGs. 7 to 9 are diagrams depicting examples of the query packet and the reply packet.

FIG. 7 depicts an example where the query packet includes the required electric power and time of use. For the query packet, the replay packet includes electric power that will be supplied, a cost (electric power selling cost), and a number of hops (distance index between the electric power consumption source and the own electric power supply source). This example assumes that only the node, which can satisfy the electric power and the time of use required in the query packet, returns the reply packet. Then, the electric power consumption source selects an optimum electric power supply source based on the cost and the number of hops. For example, the electric power consumption source calculates

$C = Cost + K \cdot hops$

where Cost is the cost, K is a constant (e.g. 5 yen), and hops is the number of hops, and select the electric power supply source with the least C. Therefore, according to local power consumption and local production, an electric power selling node with small number of hops and low price can be selected automatically.

FIG. 8 depicts an example where the query packet includes required electric power, time of use and a cost (purchase cost). For the query packet, the reply packet includes electric power that will be supplied, a cost (electric power selling cost), and a number of hops. This example assumes that even when the electric power required in the query packet is not satisfied, the reply packet can be returned. That is, returning an ambiguous reply is allowed. In

the reply packets illustrated in the example, the upper line does not satisfy the required electric power, but the cost is equivalent to the required one. The lower line satisfies the required electric power, but the cost is higher. The electric power consumption source that receives the replay packet can select the electric power supply source that satisfies the required electric power although cost is high, or can use cheap electric power by suppressing power consumption (for an air conditioner, lowering power use).

FIG. 9 depicts an example where the query packet includes required electric power, time of use and a cost (purchase cost). For the query packet, the reply packet includes electric power that will be supplied, a cost (electric power selling cost), time of use, and a number of hops. As the time of use, a time condition such as "from two hours later" or "only 10 minutes", illustrated in FIG. 9, can be entered. That is, returning an ambiguous reply regarding time is allowed. The electric power consumption source that receives the reply packet can select a cheaper electric power supply source in a case of power consumption that can be temporally changed.

<Second Embodiment>

In the second embodiment, after forming a pair by associating an electric power consumption source with an electric power supply source regarding individual power consumption by the process according to the first embodiment, the pair is exchanged for a pair formed at the other node, in order to form a more appropriate pair.

A network configuration and a configuration of the HEMS controller 4 are the same as those illustrated in FIGs. 2 and 3. However, to the consumption management unit 43 of the HEMS controller 4, a function of performing a pair exchange by using an exchange query packet is added. The supply management unit 44 may have the function of performing the pair exchange, or the consumption management unit 43 and the supply management unit 44 may have the function of performing the pair exchange.

The process, from the occurrence of electric power consumption (including scheduled consumption) until the formation of the first pair regarding the electric power consumption, is the same as illustrated in FIG. 4.

FIG. 10 is a flowchart depicting an example of a process according to the second embodiment.

In FIG. 10, the consumption management unit 43 of the HEMS controller 4 on the consumption side that has already formed a pair waits for arrival of a timing according to a periodical or random passage of time (step S201). When the timing arrives (step S201: YES), the consumption management unit 43 acquires information on electric power, electric power cost, an electric power consumption source (the own node), an electric power supply source or the like regarding the pair that has been already formed (step S202), and sends an exchange query packet requiring pair exchange in a form of a broadcast (step S203). FIG. 11 depicts an example of the exchange query packet, and includes "consumption position (electric power consumption source)", "supply position (electric power supply source)",

"electric power", "number of hops", or the like. In addition, an electric power cost or time of usage may be further included in the exchange packet.

Returning to FIG. 10, the consumption management unit 43 of the HEMS controller 4 of the other node waits for reception of an exchange query packet (step S204). When receiving the exchange query packet (step S204: YES), the exchange query packet is determined whether to arrive within a predetermined range by a broadcast (step S205). When the query packet does not arrive within the predetermined range (step S205: NO), the query packet is forwarded to the other circumferential node (step S206).

Subsequently, when a pair formed by the own node is present, the HEMS controller 4 acquires information on electric power, electric power cost, an electric power consumption source (own node), an electric power supply source, or the like regarding the pair (may be a plurality of pairs) (step S207), compares the pair indicated by the exchange query packet with the pair existing in the own node, and determines whether to perform the pair exchange taking account that the distance index decreases (step S208).

FIG. 12 is a diagram depicting an example of the determination of the pair exchange. The example assumes that a pair is formed between a node AS (consumption) and a node AD (supply), a pair is formed between a node BS (consumption) and a node BD (supply), and a pair is formed between a node CS (consumption) and a node CD (supply). Numerals between nodes indicate numbers of hops.

Here, assume that an exchange query packet is sent from the node AS (consumption), and the node BS (consumption) receives the exchange query packet. A sum of the number of hops was 10 + 10 = 20. In contrast, when the pair exchange is performed, pairs are rearranged to a pair between the node AS (consumption) and the node BD (supply) and a pair between the node BS (consumption) and the node AD (supply), a sum of the number of hops becomes 3 + 3 = 6. Because the distant index decreases, the pair exchange is determined to be performed.

Moreover, assume that the exchange query packet sent from the node AS (consumption) is received by the node CS (consumption). A sum of the number of hops was 10 + 10 = 20. In contrast, when the pair exchange is performed, pairs are rearranged to a pair between the node AS (consumption) and the node CD (supply) and a pair between the node CS (consumption) and the node AD (supply), a sum of the number of hops becomes 3 + 25 = 28. Because the distant index increases, the pair exchange is determined not to be performed.

Returning to FIG. 10, when the pair exchange is determined to be performed (step S208: YES), the record of the electric power supply of the own node is changed to the one of the new pair, and the pair exchange is reported to the counterpart node of the original pair, to change the record (step S209). Then, an exchange execution packet including information on the pair exchange is returned to the transmission source of the exchange query packet (step S210).

A node of the transmission source of the

exchange query packet waits for reception of an exchange execution packet (step S211). When receiving the exchange execution packet (step S211: YES), the node of the transmission source changes the record of electric power consumption to the one of the new pair, and the pair exchange is reported to the counterpart node of the original pair, to change the record (step S212).

In this way, also for a pair formed by chance, an automatic matching is performed asynchronously and dispersively so that a distance always becomes shorter.

<Third Embodiment>

In the second embodiment, though it is possible to guide to an ideal combination according to the pair exchange, because each node frequently sends a broadcast query, an amount of control packets is supposed to become quite great. Moreover, because the broadcast packet performs flatting, if a hop limit is not reduced, also a great amount of queries occur. Therefore, only a small range can be searched, a pair exchange is performed in a limited portion, and an effect of the pair exchange is limited.

Then, in the third embodiment, a matching server is arranged for pair exchange. Communication for the pair exchange is restricted to only with the matching server, and when an object range for the pair exchange is enlarged, the communication volume is made not to become enormous.

FIG. 13 is a diagram depicting an example configuration of a system according to the third embodiment. In FIG. 13, in addition to the configuration illustrated in FIG. 2, a matching

server 5 is installed on the control network 3.

FIG. 14 is a flowchart depicting an example of a process in the third embodiment.

In FIG. 14, the consumption management unit 43 of the HEMS controller 4 on the consumption side that has already formed a pair waits for arrival of a timing according to a periodical or random passage of time (step S301). When the timing arrives (step S301: YES), the consumption management unit 43 acquires information on electric power, electric power cost, an electric power consumption source (the own node), an electric power supply source or the like regarding the pair (step S302), and sends pair information to the matching server 5 (step S303).

The matching server 5 waits for reception of pair information (step S304). When receiving the pair information (step S304: YES), the matching server 5 retains the received pair information temporarily (step S305).

Subsequently, the matching server 5 performs matching between pairs for the plurality of pieces of pair information that are retained temporarily in terms of whether a distance index is reduced by the pair exchange or the like (step S306). When the matching is established (step S307: YES), the matching server 5 sends exchange instructions to nodes of two pairs that will be exchanged (step S308).

The node of transmission source of the pair information waits for reception of an exchange instruction (step S309). When receiving the exchange instruction (step S309: YES), the node of the transmission source changes the record of electric power consumption to the one of the new pair, and

reports the pair exchange also to the counterpart node of the original pair, to change the record (step S310).

Because each node registers its own pair information to the matching server 5 periodically or randomly, by exchanging pairs that encounter on the matching server 5 by chance, it is possible to guide to a direction that can reduce the total hop value. Possibility of performing pair exchange is determined based on a short-term storage time t1 for the pair information in the matching server 5 and a cycle t2 of registering information from nodes. That is, when t1 is set long and t2 is set short, the possibility of exchange is enhanced.

<Fourth Embodiment>

In the second embodiment, as described above, there is the potential for the amount of control packets to become quite great. In the third embodiment, the communication volume is reduced by arranging a matching server for pair exchange. However, a case where a communication volume with the matching server is not negligible can be considered, and further reduction is desired.

Then, in the fourth embodiment, virtual agents, which are synchronized with the HEMS controller respectively, are arranged on the network (cloud computing). By performing communication between the virtual agents or between the virtual agent and the matching server, the communication volume on the real network is reduced. Because the flatting of the control packet or the like is not performed on the real network, a situation where the network is filled with control packets, such as a DOS

attack, will not occur.

FIG. 15 is a diagram depicting an example configuration of the system according to the fourth embodiment. In addition to the configuration illustrated in FIG. 2 or the configuration illustrated in FIG. 13, on a new server or the matching server 5, arbitrary numbers of virtual networks 6 are arranged. The virtual networks 6 includes virtual agents 7A, 7B, 7C,… that are synchronized with states of the HEMS controllers 4A, 4B, 4C,… . When the states of the HEMS controllers 4A, 4B, 4C,… change, they are reflected in the corresponding virtual agents 7A, 7B, 7C, … . When states of the virtual agents 7A, 7B, 7C,… change, they are reflected in the HEMS controllers 4A, 4B, 4C,… . When the plurality of virtual networks 6 are present, a pair of supply and acceptance of electric power is assumed to be closed inside the virtual network.

As the other process, the process for forming a pair when power consumption occurs is the same as that illustrated in FIG. 4. Regarding the process of exchanging pair, processes on the consumption side and of the other node in FIG. 10 are performed by the virtual agent 7 by proxy, and a state of a result is reflected to the respective HEMS controller 4. Moreover, regarding the process of exchanging pair by using the matching server 5, the processes on the consumption side and of the original and new counterpart nodes are in FIG. 14 are performed by the virtual agent 7 by proxy, and a state of a result is reflected to the respective HEMS controller 4.

<Fifth Embodiment>

The fifth embodiment is an extension of the fourth embodiment, i.e. in order to mitigate an influence of a user who has a lot of specific demands regarding a pair of a certain distance (within a region), virtual networks are shuffled randomly at a predetermined timing so that pairs inside the region are not fixed.

FIG. 16 is a diagram depicting an example of shuffle of the virtual network according to the fifth embodiment, and illustrates a state where, as illustrated in an upper part, virtual agents in a certain region stored in a certain virtual network are randomly shuffled and stored in a different virtual network. By making pairs of supply and acceptance of electric power closed inside the same virtual network, responses to demands are prevented from being eccentrically located in a specific user, because an object range of a counterpart node that forms the pair changes.

The pair formed before the shuffle continues until the supply and acceptance of electric power end or until a pair exchange is performed. Moreover, the pair exchange or a new pair formation is performed inside a virtual network that is newly stored.

<Sixth Embodiment>

In the third embodiment, the increase of control packets in the second embodiment is solved by arranging a matching server. However, the sixth embodiment solves without using the matching server, but by the P2P (Point To Point) technology. That is, the increase of control packets is suppressed without

sending (forwarding) exchange query packets in all directions except an entrance by broadcasting, but by sending (forwarding) in a random direction except the entrance, when the pair exchange is not performed in the own node, until reaching the hop limit.

FIG. 17 is a flowchart depicting an example of a process according to the sixth embodiment.

In FIG. 17, the consumption management unit 43 of the HEMS controller 4 on the consumption side that has already formed a pair waits for arrival of a timing according to a periodical or random passage of time (step S401). When the timing arrives (step S401: YES), the consumption management unit 43 acquires information on electric power, electric power cost, an electric power consumption source (the own node), an electric power supply source or the like regarding the pair (step S402), and sends an exchange query packet requiring pair exchange in a random direction (step S403).

The consumption management unit 43 of the HEMS controller 4 of the other node waits for reception of the exchange query packet (step S404). When receiving the exchange query packet (step S404: YES), when there is a pair formed in the own node, the consumption management unit 43 acquires information on electric power, electric power cost, an electric power consumption source (the own node), an electric power supply source or the like regarding the pair (may be a plurality of pairs) (step S405).

Subsequently, the consumption management unit 43 compares the pair indicated by the exchange query packet and the pair existing in the own node, and determines whether to perform the pair exchange

taking account that the distance index decreases (step S406).

When determining not to perform pair exchange (step S406: NO), the consumption management unit 43 determines whether to reach a predetermined range such as a hop limit (step S407). When not reaching the predetermined range (step S407: NO), the consumption management unit 43 forwards a query packet in a random direction except the entrance (step S408).

Moreover, when determining to perform pair exchange (step S406: YES), the consumption management unit 43 changes the record of electric power supply of the own node to the one of the new pair, and reports the pair exchange also to the counterpart node of the original pair, to change the record (step S409). Then, an exchange execution packet including information of the pair exchange is returned to the node of the transmission source of the exchange query packet (step S410).

The node of the transmission source of the exchange query packet waits for receiving the exchange execution packet (step S411). When receiving the exchange execution packet (step S411: YES), the node of the transmission source changes the record of electric power consumption to the one of the new pair, and reports the pair exchange to also the counterpart node of the original pair to change the record (step S412).

FIG. 18 is a diagram depicting an example of transmission of an exchange query according to the sixth embodiment, and illustrates as an example a Manhattan network (network having a grid pattern).

Considering a case of a relatively large Manhattan network, a forwarding destination of the exchange query packet performs a random walk without going back at each intersection. In the example illustrated in FIG. 18, an exchange query packet sent from the electric power consumption source S first encounters a node A. When a cost reduction effect by pair exchange is not present, forwarding the exchange query packet is continued. Then, the exchange query packet encounters a node E by change, performs the pair exchange, and thereby reduces the cost.

<Seventh Embodiment>

In the seventh embodiment, the process of pair formation by query packet (FIG. 4), performed in the first embodiment, is not performed, but a pair is forced to be formed with an initial supply source that had been secured in advance, and thereby it is possible to promptly respond to an electric power consumption. Then, by performing the pair exchange described in the second to sixth embodiments, recombination is performed toward more appropriate pair.

As prerequisite for the process, a node that can supply electric power is necessarily secured, as an initial supply source. Moreover, after forming a pair, in preparation for newly occurring demand, an initial supply source is provided. For example, the electric power supply source is secured by turning ON a predetermined electric power generation device within the control network 3, or by making contact with an electric power company.

FIG. 19 is a flowchart depicting an example of a process according to the seventh embodiment.

In FIG. 19, the consumption management unit 43 of the HEMS controller 4 on the consumption side waits for an occurrence of power consumption (including scheduled consumption) (step S501). When the occurrence occurs (step S501: YES), the consumption management unit 43 acquires information on required electric power, time of use, or the like (step S502), and records acceptance of electric power where the initial supply source serves as an electric power supply source (step S503). The consumption management unit 43 causes the initial supply source side that forms the pair to record the electric power supply.

Therefore, there is an advantage that when starting use of an electric appliance, time for searching an electric power supply source is unnecessary, and the cost of the entire network will be reduced at some stage.

<Eighth Embodiment>

In the eighth embodiment, based on a property of each electric appliance that the HEMS controller 4 of each home 1 stores, appropriate procurement of electric power is performed.

An electric appliance in a home has priority for each of the time (clock time), temperature, power consumption, or the like. For example, when laundry is desired to be finished by 4 o'clock or when an EV is desired to be charged by 4 o'clock, the priority is low when sufficient time is present. However, when it becomes close to a deadline, the priority increases. FIG. 20A illustrates an example where the priority changes depending on time in this way, and is the maximum at

the deadline (deadline type). The time of deadline is denoted by t_{must}.

Moreover, for a refrigerator, when the electric power is OFF, where is not a problem. However, when a door is opened and closed several times, temperature inside the refrigerator increases, and accordingly the priority changes. FIG. 20B illustrates an example where the priority changes depending on the temperature in this way. The permissible temperature for preserving food is denoted by $temp_{enable}$.

Moreover, priorities may be different between changing a setting among strong/weak for air conditioner or darken a light slightly and turning off completely. FIG. 20C illustrates an example where the priority changes depending on electric power in this way. The least permissible electric power is denoted by p_{min}.

Therefore, when an electric power demand occurs in home, preference orders of procurement for electric power are assigned depending on priorities of electric appliances requiring electric power. For the electric appliance with low priority, use thereof is delayed, or, if possible, electric power is reduced.

However, because when a specific electric appliance cannot be used frequently, it is inconvenient for a user, QoS degradation is observed for each electric appliance, and when the QoS degradation is observed, priority characteristic is set in a direction for enhancing the priority. Moreover, on this occasion, taking account of fairness with other home, when priority of a part of

electric appliance is set to be higher, priority characteristic of the other electric appliance is set in a direction for lowering the priority.

FIG. 21 is a flowchart depicting an example of a process according to the eighth embodiment.

In FIG. 21, the consumption management unit 43 of the HEMS controller on the consumption side waits for arrival of a timing according to a periodical passage of time (step S601). When the timing arrives (step S601: YES), the consumption management unit 43 acquires information on a type, a configuration state, a QoS degradation record or the like regarding electric appliances to be stored (step S602), and sets a priority curve for each electric appliance (step S603). As the priority curve, curves illustrated in FIGs. 20A to 20C are exemplified.

Here, regarding an electric appliance, in which QoS degradation is not detected for the first time or within a past predetermined period of time, a standard priority curve is set in principle. An electric appliance, in which QoS degradation is detected within the past predetermined period of time, is set in the direction for making the priority higher than before. In FIG. 22, a priority curve of the deadline type is indicated by a solid line for the first time, next by a dashed-dotted line, and next by a dashed-two dotted line. Moreover, when priority of a part of electric appliance is set to be higher, a priority curve of the other electric appliance is set in a direction for lowering the priority.

Returning to FIG. 21, the consumption management unit 43 monitors QoS degradation for each

electric appliance, and when QoS degradation is detected (step S606: YES), records that effect (step S605).

In contrast, the consumption management unit 43 waits for an occurrence of power consumption (including scheduled consumption) (step S606). When power consumption occurs (step S606: YES), the consumption management unit 43 acquires information on electric power, time of use, an ID of electric appliance, deadline, temperature, the least electric power, or the like (step S607), and acquires current priority from the priority curve that is preliminarily set for each electric appliance (step S608).

Subsequently, a cost (purchase cost) depending on the priority is acquired (step S609). For example, the cost is increased depending on the priority. Then, a query packet for requiring necessary electric power supply is sent (step S610). Processes after sending the query packet are the same as those illustrated in FIG. 4.

In addition, the query packet may have priority, and the node of the electric power supply source may reply taking account of the priority.

In this way, by controlling electric appliances, so that QoS degradation is not observed as much as possible, the electric appliances operate in learning type, and appropriate procurement of electric power can be performed.

<Ninth Embodiment>

In the eighth embodiment, detection of QoS degradation is supposed to be performed automatically. In the ninth embodiment, further declaration for QoS

degradation by a user himself/herself is used. That is, as a user interface of the HEMS controller 4, a button for inputting discomfort feeling for controlling ("dislike" button) is provided. When the user feels uncomfortable for an automatic control by a system (for example, an electric appliance is desired to be used but cannot be used), the user is caused to press the button.

FIG. 23 is a flowchart depicting an example of a process according to the ninth embodiment. In FIG. 23, the information input unit 42 of the HEMS controller 4 waits for pressing the "dislike" button by the user (step S701), and when the "dislike" button is pressed (step S701: YES), records that effect (step S702).

The control process is the same as that illustrated in FIG. 21, but different in that on acquiring information (step S602), a record of a number of times of pressing the "dislike" button within a predetermined time period is referred to and is reflected to the setting of the priority curve (step S603) (The greater the number of times of pressing the "dislike" button is, the less effective the control depending on the priority is).

Moreover, on the number of times of the "dislike" button, an upper limit is put. The priority, which corresponds to personal preference of each user as much as possible, can be formed carrying a penalty, such as free of charge up to 10 times, 500 yen for 10 to 20 times, and 1000 yen for 20 to 30 times. That is, a system is provided where by pressing the "dislike" button, the priority curve is changed and the control becomes less effective, and

at the same time, a total electricity rate increases by that amount.

<Tenth Embodiment>

In the tenth embodiment, between users who perform supply and acceptance of electric power, reliability of the counterparts can be verified.

FIG. 24 is a diagram depicting an example configuration of a system according to the tenth embodiment. On the control network 3 that exchanges a query, an authentication server 8 is newly arranged. The authentication server 8 retains information regarding inappropriate transactions.

Each HEMS controller 4 can query the authentication server 8 about reliability of received query or query reply. The authentication server 8 determines the reliability of the query based on the retained information regarding inappropriate transactions, and offers a response.

<Summary>

As described above, according to the embodiments, a mechanism that can supply electric power dispersively for individual electric power consumptions can be provided.

As described above, the present invention is described by the preferred embodiment of the present invention. Here, the present invention is explained illustrating specific examples. However, it is apparent that various variations and modifications of the specific examples may be made without departing from the broad effect and the scope of the invention as set forth in the accompanying claims. That is, the present invention should not be limited to the details of the specific examples and

accompanying drawings.

The present international application is based on Japanese Priority Application No. 2014-085848 filed on April 17, 2014, with the Japanese Patent Office, the entire contents of Japanese priority application No. 2014-085848 are hereby incorporated by reference.

[Reference Signs List]

1,1A-1C home
2 electric distribution network
3 control network
4,4A-4C HEMS controller
41 information display unit
42 information input unit
43 consumption management unit
44 supply management unit
45 packet transmission/reception unit
5 matching server
6 virtual network
7,7A-7C virtual agent
8 authentication server

WHAT IS CLAIMED IS

[Claim 1]

A power control network system, in which a plurality of electric power supply sources and a plurality of electric power consumption sources are coupled via an electric power transmission network, and which is provided with a control network overlaid on the electric power transmission network,

wherein a node corresponding to an electric power consumption source in the control network includes:

a query packet transmission means for sending a query packet requiring necessary electric power supply to a circumferential node, when electric power consumption is required in the node;

a reply packet reception means for receiving a reply packet, which is a response to the query packet; and

a consumption management means for selecting an electric power supply source that covers the electric power consumption requirement based on the received reply packet,

wherein the node corresponding to the electric power consumption source or the electric power supply source further includes:

an exchange query packet transmission means for sending, to another circumferential node, an exchange query packet that requires a pair exchange regarding a pair of an own node and a counterpart node that have already been associated

with power consumption and power supply for a predetermined electric power;

an exchange execution packet reception means for receiving an exchange execution packet, which is a response to the exchange query packet; and

a pair exchange means for performing the pair exchange according to the received exchange execution packet, and

wherein a node corresponding to another electric power consumption source or another electric power supply source includes:

an exchange query packet reception means for receiving the exchange query packet;

a pair exchange determination means for comparing a pair with another counterpart node that an own node already retains with the pair indicated by the exchange query packet, and determining whether to perform the pair exchange taking into account that a distance index decreases; and

an exchange execution packet transmission means for performing the pair exchange when the pair exchange is determined to be performed, and sending the exchange execution packet.

[Claim 2]

The power control network system according to claim 1,

wherein the node corresponding to the electric power supply source in the control network further includes:

a query packet reception means for receiving the query packet from the circumferential node; and

a reply packet transmission means for sending the reply packet including an electric power cost and a distance index, and

wherein the consumption management means in the node corresponding to the electric power consumption source selects an optimum electric power supply source based on the electric power cost and the distance index included in the reply packet.

[Claim 3]

The power control network system according to claim 2,

wherein the reply packet transmission means sends the reply packet including electric power that can be supplied, even when the electric power that can be supplied is insufficient for the required electric power by the query packet, and

wherein the consumption management means selects an electric power supply source taking into account whether power consumption can be reduced.

[Claim 4]

The power control network system according to claim 2,

wherein the reply packet transmission means sends the reply packet including time

condition in which electric power can be supplied, and

wherein the consumption management means selects the electric power supply source taking into account the time condition.

[Claim 5]

The power control network system according to claim 1,

wherein the node corresponding to the electric power consumption source or the electric power supply source further comprises:

a pair information transmission means for sending, to a matching server, pair information on the pair of the own node and the counterpart node that have already been associated with power consumption and power supply for the predetermined electric power requirement, and

wherein the pair exchange means is further configured for receiving pair exchange information from the matching server.

[Claim 6]

The power control network system according to claim 1 further comprising:

a means, as virtual agents existing on any server, corresponding to the nodes respectively, for performing synchronization of states with the corresponding nodes, and performing a process of

the pair exchange on behalf of the nodes.

[Claim 7]

The power control network system according to claim 6 further comprising:

a means for storing the virtual agents into any virtual network, and shuffling randomly the virtual agents stored in the virtual network at a predetermined timing.

[Claim 8]

The power control network system according to claim 1,

wherein the exchange query packet transmission means sends an exchange query packet randomly to any adjacent node, and

wherein the node corresponding to the other electric power consumption source forwards the exchange query packet randomly to any adjacent node except a reception source, when the pair exchange is not executed.

[Claim 9]

The power control network system according to claim 1,

wherein the consumption management means, when electric power consumption is required in the electric power consumption source, does not use the

query packet transmission means, but selects an electric power supply source that covers the electric power consumption from electric power supply source candidates that have been prepared in advance.

[Claim 10]

The power control network system according to claim 1,

wherein each node includes:

a means for configuring priority characteristics representing a preference order of electric power supply depending on a situation for each of electric appliances that the node stores;

a means for monitoring and recording QoS degradation of electric power supply for each of the electric appliances; and

a means for reconfiguring the priority characteristic in a direction of enhancing the preference order, when the QoS degradation is recorded, and reconfiguring priority characteristics of the other electric appliance in a direction of lowering a preference order.

[Claim 11]

The power control network system according to claim 10 further comprising:

a means for providing an interface of a button for inputting discomfort feeling for control

by a user,

wherein a number of times of pressing the button is reflected to the QoS degradation.

[Claim 12]

The power control network system according to claim 1 further comprising:

a means for retaining information regarding inappropriate transactions, and returning reliability of a query in response to an inquiry of the node.

[Claim 13]

A control device configuring a node in a control network of a system, in which a plurality of electric power supply sources and a plurality of electric power consumption sources are coupled via an electric power transmission network, and which is provided with the control network overlaid on the electric power transmission network, comprising:

a query packet transmission means for sending a query packet requiring necessary electric power supply to a circumferential node, when electric power consumption is required in the node;

a reply packet reception means for receiving a reply packet, which is a response to the query packet;

a consumption management means for

selecting an electric power supply source that covers the electric power consumption based on the received reply packet;

an exchange query packet transmission means for sending, to another circumferential node, an exchange query packet that requires a pair exchange regarding a pair of an own node and a counterpart node that have already been associated with power consumption and power supply for a predetermined electric power;

an exchange execution packet reception means for receiving an exchange execution packet, which is a response to the exchange query packet;

a pair exchange means for performing the pair exchange according to the received exchange execution packet; and

a pair exchange determination means for comparing a pair with another counterpart node that an own node already retains with a pair indicated by another exchange query packet, and determining whether to perform a pair exchange taking into account that a distance index decreases; and

an exchange execution packet transmission means for performing the pair exchange when the pair exchange is determined to be performed based on the other exchange query packet, and sending an exchange execution packet.

[Claim 14]

A control program for causing a computer configuring a device that has a node in a control

network of a system, in which a plurality of electric power supply sources and a plurality of electric power consumption sources are coupled via an electric power transmission network, and which is provided with the control network overlaid on the electric power transmission network, to function as

a query packet transmission means for sending a query packet requiring necessary electric power supply to a circumferential node, when electric power consumption is required in the node;

a reply packet reception means for receiving a reply packet, which is a response to the query packet;

a consumption management means for selecting an electric power supply source that covers the electric power consumption requirement based on the received reply packet;

an exchange query packet transmission means for sending, to the circumferential node, an exchange query packet that requires a pair exchange regarding a pair of an own node and a counterpart node that have already been associated with power consumption and power supply for a predetermined electric power;

an exchange execution packet reception means for receiving an exchange execution packet, which is a response to the exchange query packet;

a pair exchange means for performing the pair exchange according to the received exchange execution packet;

a pair exchange determination means for comparing a pair with another counterpart node that

an own node already retains with a pair indicated by another exchange query packet, and determining whether to perform the pair exchange taking into account that a distance index decreases; and

an exchange execution packet transmission means for performing the pair exchange when the pair exchange is determined to be performed based on the other exchange query packet, and sending an exchange execution packet.

[Claim 15]

A power control network system, in which a plurality of electric power supply sources and a plurality of electric power consumption sources are coupled via an electric power transmission network, and which is provided with a control network overlaid on the electric power transmission network,

wherein a node corresponding to an electric power consumption source in the control network includes:

a query packet transmission means for sending a query packet requiring necessary electric power supply to a circumferential node, when electric power consumption is required in the node;

a reply packet reception means for receiving a reply packet, which is a response to the query packet; and

a consumption management means for selecting an electric power supply source that covers the electric power consumption requirement based on the received reply packet; and

wherein the node corresponding to the electric

power consumption source or the electric power supply source further includes:

a pair information transmission means for sending pair information for pair exchange regarding a pair of an own node and a counterpart node that have already been associated with power consumption and power supply for a predetermined electric power requirement with a pair at a node corresponding to another electric power consumption source or another electric power supply source, wherein the pair information transmission means sends the pair information for the pair exchange to a matching server; and

a pair exchange means for receiving pair exchange information from the matching server, and performing the pair exchange.