

DESCRIPTION

DISTRIBUTION BOARD AND POWER LINE COMMUNICATION SYSTEM

5 Technical Field

[0001] The present invention relates to a distribution board and a power line communication system that use a power line to supply power as a signal communication line.

10 Background Art

[0002] Power line communication (PLC) systems use power lines to supply power as signal communication lines. The power line communication systems are used as indoor communication systems due to less electromagnetic wave leakage. For such a power line communication system, a dedicated communication device (PLC modem) as
15 disclosed in Japanese Patent Application Kokai Publication No. 2018-23076 (Patent Document 1). PLC modems in general are electrically connected to electrical outlets to supply power, thereby allowing power line communication between a plurality of home appliances.

[0003] Fig. 1 is a schematic diagram of a power line communication system in the past and illustrates electrical connection of a distribution board 1, electrical outlets 5, PLC
20 modems 6, and a plurality of home appliances 7. The distribution board 1 includes a main breaker 2, a plurality of branch breakers 3, and a bus 8. For simplification of the drawing, the number of branch breakers 3 is given as three. A secondary side of the respective branch breakers 3 are electrically connected to the three electrical outlets 5 via
25 power lines 4. Each electrical outlet 5 is electrically connected to the PLC modem 6 and the plurality of home appliances 7. Arrows in Fig. 1 illustrate signal paths for power line communication from one of the PLC modems 6 to another PLC modems 6. A signal sent from the one PLC modem 6 passes from one of the electrical outlets 5 through one of the power lines 4 and reaches one of the branch breakers 3 in the distribution board 1.
30 After that, the signal passes from the bus 8 in the distribution board 1 through another branch breaker 3 and another power line 4 and is received by another PLC modem 6.

Prior Art Documents

Patent Document

35 [0004] Patent Document 1: Japanese Patent Application Kokai Publication No. 2018-23076

Disclosure of the Invention

Problems to be solved by the Invention

[0005] The power line communication system in the past illustrated in Fig. 1, however, has a problem that the waveforms of signals sent from the PLC modems 6 are prone to be attenuated. The thickness of the arrow lines in Fig. 1 represents attenuation of the signal waveform. The attenuation of the signal waveform may be caused by, for example, a capacitor built in any of the home appliances 7 that attenuates the waveform of a signal sent from the PLC modem 6. In addition, due to the small wire diameter and high impedance, the residential power lines 4 attenuates the waveform of a signal sent from the PLC modem 6. Further, in Fig. 1, a signal of one of the PLC modems 6 is branched by the branch breakers 3 and sent to another PLC modem 6 as a communication target and the third PLC modem 6 not as the communication target. The power line communication system in the past thus has a problem that the signal waveform is attenuated and the communication rate decreases due to the influence of the home appliances 7, the wire diameters of the power lines 4, the lengths of the signal paths, and the like. Accordingly, when high quality of communication is expected in a building, there used to be no alternatives but to add dedicated communication lines.

[0006] The present invention has been made to solve the problems in the past described above and it is an object thereof to provide a distribution board and a power line communication system that are capable of reconstructing attenuation of a signal waveform and greatly improving quality of communication using a power line.

Means to solve the Problems

[0007]

(1) To achieve the above object, a distribution board of the present invention includes: a main breaker; a bus; and a plurality of branch breakers, each of the plurality of branch breakers electrically connected to a secondary side of the main breaker via the bus, wherein

the distribution board further includes a PLC modem electrically connected to a primary side of the main breaker or, via the bus, the secondary side of the main breaker and a primary side of the branch breakers, and the PLC modem is configured to amplify a received signal and send the signal via a power line.

[0008]

(2) To achieve the above object, a first power line communication system of the

present invention includes a plurality of distribution boards electrically connected via at least one power line, each of the plurality of distribution boards including a main breaker, a bus, and a plurality of branch breakers, and each of the plurality of branch breakers electrically connected to a secondary side of the main breaker via the bus, wherein

5 each of the distribution boards further includes a PLC modem electrically connected to a primary side of the main breaker or, via the bus, the secondary side of the main breaker and a primary side of the branch breakers, and the PLC modem is configured to amplify a received signal and send the signal, and

 the signal sent from one of the PLC modems is received by another of the PLC
10 modems via the power line.

[0009]

(3) It is preferred that, in the power line communication system according to (2) above, the primary side of the main breaker in each of the distribution boards is serially connected by the power line.

15 [0010]

(4) It is preferred that, in the power line communication system according to (2) or (3) above, the PLC modem in any one of the distribution boards is configured to relay sending and receiving of the signal between the PLC modems in other two of the distribution boards.

20 [0011]

(5) It is preferred that, in the power line communication system according to any one of (2) through (4) above, the PLC modem in each of the distribution boards is electrically connected to the primary side of the main breaker.

[0012]

25 (6) It is preferred that, in the power line communication system according to any one of (2) through (5) above, the PLC modem in each of the distribution boards receives the signal via any one of the branch breakers.

[0013]

(7) To achieve the above object, a second power line communication system of the
30 present invention includes: at least one parent distribution board and a plurality of child distribution boards, the parent and child distribution boards being electrically connected via a plurality of power lines, each of the parent and child distribution boards including a main breaker, a bus, and a plurality of branch breakers, each of the branch breakers being electrically connected to a secondary side of the main breaker via the bus, a primary side
35 of the main breaker in the parent distribution board being electrically connected to an incoming line of power, and a secondary side of at least one of the branch breakers in the

parent distribution board being electrically connected to a primary side of at least one of the main breakers in the child distribution boards via the respective power lines, wherein

the parent distribution board further includes a parent PLC modem electrically connected to the secondary side of the main breaker and a primary side of the branch breakers via the bus,

each of the child distribution boards further includes a child PLC modem electrically connected to the primary side of the main breaker,

the child PLC modems are configured to receive a signal via at least one of the branch breakers in the child distribution boards, amplify the signal, and send the signal via the respective power lines, and

the parent PLC modem is configured to receive the signal via the respective power lines, amplify the signal, and send the signal.

[0014]

(8) It is preferred that the power line communication system according to (7) above includes at least two of the child distribution boards, wherein

the parent PLC modem is configured to relay sending and receiving of the signal between the child PLC modems in two of the child distribution boards.

Effects of the Invention

[0015] The distribution board and the power line communication system of the present invention are capable of reconstructing attenuation of a signal waveform and greatly improving quality of communication using a power line.

Brief Description of the Drawings

[0016] Fig. 1 is a schematic diagram illustrating a power line communication system in the past.

Fig. 2 is a schematic diagram illustrating a power line communication system according to a first embodiment of the present invention.

Fig. 3 is a flowchart illustrating a signal path of intra-room LAN communication 1.

Fig. 4 is a flowchart illustrating a signal path of intra-room LAN communication 2.

Fig. 5 is a flowchart illustrating a signal path of intra-room LAN communication 3.

Fig. 6 is a flowchart illustrating a signal path of inter-room LAN communication 1.

Fig. 7 is a flowchart illustrating a signal path of inter-room LAN communication 2.

Fig. 8 is a flowchart illustrating a signal path of inter-room LAN communication 3.

5 Fig. 9 is a flowchart illustrating a signal path of inter-room LAN communication 4.

Fig. 10 is a flowchart illustrating a signal path of inter-room LAN communication 5.

10 Fig. 11 is a flowchart illustrating a signal path of WAN communication using a grandchild PLC modem.

Fig. 12 is a flowchart illustrating a signal path of WAN communication using a local controller.

Fig. 13 is a schematic diagram illustrating a power line communication system according to a second embodiment of the present invention.

15 Fig. 14 is a schematic diagram illustrating an example of a mode of using the power line communication system illustrated in Fig. 2.

Modes for Carrying Out the Invention

[0017] 1. First Embodiment

20 At first, with reference to Fig. 2, a description is given to the first embodiment of a power line communication system including a distribution board of the present invention.

[0018] 1.1 Overview of Power Line Communication System

25 As illustrated in Fig. 2, the power line communication system in the present embodiment includes a parent distribution board 10 and three child distribution boards 20. The parent distribution board 10 and three child distribution boards 20 are respectively installed, for example, in different rooms or on different floors in one building. It should be noted that installation sites of the parent distribution board 10 and the three child distribution boards 20 are not particularly limited. For example, the
30 power line communication system in the present embodiment is applied to a regular house. For example, the parent distribution board 10 is installed in a living room L and the three child distribution boards 20 are respectively installed in rooms R1, R2, and R3 other than the living room L. The respective rooms R1, R2, and R3 are provided with electrical outlets 5 and various home appliances 7 are installed therein. It should be noted that the
35 living room L is also provided with electrical outlets, not shown, and various home appliances are installed therein.

[0019] The parent distribution board 10 is provided with a parent PLC modem 16, a broadband network gateway 17, and a local controller 18. Each of the three child distribution boards 20 is provided with a child PLC modem 23 and a local controller 24. To each electrical outlet 5 in the rooms R1, R2, and R3, a grandchild PLC modem 25 with an outlet plug is electrically connected. The term "PLC modem" herein widely includes configurations that are capable of superimposing a carrier wave conveying a signal used for data communication on a power line and separating the carrier wave from the power line.

[0020] The parent PLC modem 16 communicates with a broadband network via the broadband network gateway 17. The parent PLC modem 16 also communicates with the child PLC modems 23 of the respective three child distribution boards 20 via power lines 14. The parent PLC modem 16 further communicates with home appliances, not shown, installed in the living room L via the local controller 18.

[0021] As described above, the child PLC modems 23 communicate with the parent PLC modem 16 via the power lines 14. Each child PLC modem 23 also communicates with the respective child PLC modems 23 of the other two child distribution boards 20 via power lines 15. The child PLC modems 23 further communicate with the grandchild PLC modems 25 via power lines 4. In addition, the child PLC modems 23 communicate with the home appliances 7 installed in any of the rooms R1, R2, and R3 via the local controllers 24.

[0022] 1.2 Parent Distribution board

The parent distribution board 10 is provided with a main breaker 11, a bus 12, four branch breakers 13, the parent PLC modem 16 described above, the broadband network gateway 17 described above, and the local controller 18 described above. A primary side of the main breaker 11 is electrically connected to an incoming line of power. The power provided from a power company is supplied via the incoming line from the primary side of the main breaker 11 to the parent distribution board 10.

[0023] A secondary side of the main breaker 11 is electrically connected to the bus 12. To the bus 12, the four branch breakers 13 are electrically connected. A secondary side of one of the branch breakers 13 is electrically connected to the child distribution board 20 in the room R1 via one of the power lines 14. The power lines 14 are electric wires with a large wire diameter to electrically connect the plurality of distribution boards. Secondary sides of the respective remaining three branch breakers 13 are electrically connected to air conditioners 19 with high power consumption.

[0024] The parent PLC modem 16 is electrically connected to the secondary side of the main breaker 11 and primary sides of the four branch breakers 13 via the bus 12. To

the parent PLC modem 16, the broadband network gateway 17 and the local controller 18 are electrically connected. The parent PLC modem 16 superimposes a high frequency signal (hereinafter, simply referred to as a “signal”), such as data and information, on the power lines and separates the signal from the power lines. The parent PLC modem 16
5 also amplifies the received signal and sends the signal. The parent PLC modem 16 is further capable of encrypting the signal and sending it. The encrypted signal is decrypted using a common key.

[0025] The broadband network gateway 17 relays between the parent PLC modem 16 and the broadband network. The parent PLC modem 16 is capable of high-capacity
10 Internet communication via the broadband network gateway 17.

[0026] The local controller 18 has a configuration capable of sending and receiving signals to and from home appliances, not shown, installed in the living room L by wired or wireless communication. Examples of the wireless communication include communication mechanisms, such as Wi-Fi®, Bluetooth®, and infrared rays. Examples
15 of the wired communication include wired LAN using metal cables or optical fibers.

[0027] 1.3 Child Distribution board

Each of the three child distribution boards 20 is provided with a main breaker 21, a plurality of branch breakers 22, the child PLC modem 23 described above, and the local controller 24 described above. As described above, a primary side of the main
20 breaker 21 of the child distribution board 20 in the room R1 is electrically connected to one of the branch breakers 13 in the parent distribution board 10 via the corresponding power line 14. The three child distribution boards 20 are transition wired in the order of the rooms R1, R2, and R3 by the power lines 15. The transition wiring is a wiring system to serially connect a plurality of devices in order. The power lines 15 are electric
25 wires with a large wire diameter to electrically connect the plurality of distribution boards. Power is supplied to the main breaker 21 of the child distribution board 20 in the room R1 and, via the transition wired power lines 15, supplied to the respective child distribution boards 20 in the rooms R2 and R3.

[0028] To a secondary side of the main breaker 21, three or two branch breakers 22
30 are electrically connected. The secondary side of at least one of the branch breakers 22 is electrically connected to the corresponding electrical outlet 5 via a power line 4. The power line 4 is residential wiring with a small wire diameter. Each electrical outlet 5 is electrically connected to the grandchild PLC modem 25 described above.

[0029] To the primary side of the main breaker 21 in each child distribution board 20,
35 the child PLC modem 23 is electrically connected. To the child PLC modem 23, the local controller 24 is electrically connected. The child PLC modem 23 has the same

functions as those of the parent PLC modem 16. That is, the child PLC modem 23 superimposes a signal on the power lines and separates the signal from the power lines. The child PLC modem 23 also amplifies the received signal. The child PLC modem 23 is further capable of encrypting the signal and sending it. The encrypted signal is decrypted using a common key.

[0030] The local controller 24 of each child distribution board 20 has the same functions as those of the local controller 18 of the parent distribution board 10. That is, the local controller 24 has a configuration capable of sending and receiving signals to and from the home appliances 7 installed in any of the rooms R1, R2, and R3 by wired or wireless communication. Examples of the home appliances 7 in this context include lighting fixtures; television sets; refrigerators; microwave ovens; smartphones; smart speakers; various measuring devices; sensors, such as motion sensors and temperature sensors; and remote controllers. The local controllers 24 are capable of sending and receiving signals with the air conditioners 19.

[0031] 1.4 Grandchild PLC Modem

The grandchild PLC modems 25 are provided with plugs to be plugged in and out of, for example, the electrical outlets 5 and directly electrically connected to the electrical outlets 5. To the grandchild PLC modems 25, the home appliances 7 are electrically connected that are Internet connectable IoT (Internet of Things) appliances, such as personal computers and network audio players, and are other home appliances capable of power line communication. The grandchild PLC modems 25 superimpose a signal on the power lines 4 and separate the signal from the power lines 4.

[0032] Each grandchild PLC modem 25 is also capable of setting strength of a signal to be sent. Higher signal strength causes relatively low attenuation of the signal waveform and stabilizes power line communication between the plurality of home appliances 7. Meanwhile, low signal strength causes reduction in interference of signals sent from the respective home appliances 7. The signal strength may be set in accordance with a communication range of each grandchild PLC modem 25. For example, for intra-room communication in the room R1, a signal from the grandchild PLC modem 25 is set to have high strength. For inter-room communication between the different rooms R1, R2, and R3, a signal from the grandchild PLC modem 25 is set to have low strength. These settings reduce interference of a plurality of signals in one building.

[0033] 1.5 Communication Method by Power Line Communication System

The plurality of home appliances 7 installed in the rooms R1, R2, and R3 are capable of performing local area network (LAN) communication and wide area network

(WAN) communication by the power line communication system in the present embodiment. Figs. 3 through 10 are flowcharts illustrating signal paths of eight aspects in LAN communication. Figs. 11 and 12 are flowcharts illustrating signal paths of two aspects in WAN communication. With reference to Figs. 3 through 12, a description is given below to communication methods by the power line communication system. It should be noted that (L), (R1), (R2), and (R3) in Figs. 3 through 12 refer to the rooms where the parent distribution board 10, the child distribution boards 20, the home appliances 7, and the like are installed and are used to describe the communication methods below.

10 [0034] 1.5.1 LAN Communication

Intra-Room LAN Communication

For example, the plurality of home appliances 7 installed in the same room R1 are capable of performing LAN communication by signal paths of three aspects illustrated in Figs. 3 through 5.

15 [0035] First Aspect

Fig. 3 illustrates a signal path of LAN communication using two of the grandchild PLC modems 25 installed in the same room R1.

[0036] In Fig. 3, a signal sent from a first home appliance 7 (R1) is received by a first grandchild PLC modem 25 (R1). The signal received by the first grandchild PLC modem 25 (R1) is received by the child distribution board 20 installed in the room R1 via a first power line 4 (R1). The signal received by the child distribution board 20 is sent to a second grandchild PLC modem 25 (R1) via a first branch breaker 22 (R1), a second branch breaker 22 (R1), and a second power line 4 (R1). The signal received by the second grandchild PLC modem 25 (R1) is sent to a second home appliance 7 (R1). The second home appliance 7 (R1) executes a process based on the received signal.

[0037] Second Aspect

Fig. 4 illustrates a signal path of LAN communication using two of the grandchild PLC modems 25 installed in the same room R1, which passes through the child PLC modem 23 of the child distribution board 20 installed in the room R1.

[0038] In Fig. 4, a signal sent from the first home appliance 7 (R1) is received by the first grandchild PLC modem 25 (R1). The signal received by the first grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in the room R1 via the first power line 4 (R1). The signal received by the child distribution board 20 is sent to a child PLC modem 23 (R1) via the first branch breaker 22 (R1) and a main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The

signal amplified by the child PLC modem 23 (R1) is sent to the second grandchild PLC modem 25 (R1) via the main breaker 21 (R1), the second branch breaker 22 (R1), and the second power line 4 (R1). The signal received by the second grandchild PLC modem 25 (R1) is sent to the second home appliance 7 (R1). The second home appliance 7 (R1) executes a process based on the received signal.

[0039] The signal path of the LAN communication illustrated in Fig. 4 allows reconstruction of the waveform of the signal attenuated over the course of the power line communication by the amplification function of the child PLC modem 23. That is, the signal sent from the first home appliance 7 passes through the first and second power lines 4 before being received by the second home appliance 7. The residential power lines 4 with a small wire diameter and high impedance cause attenuation of the waveform of the passing signal. The child PLC modem 23 amplifies the signal having passed through the first power line 4 to reconstruct the attenuated signal waveform. The power line communication of the plurality of home appliances 7 installed in the same room R1 is thus stabilized.

[0040] Third Aspect

Fig. 5 illustrates a signal path of LAN communication using one of the grandchild PLC modems 25 and the local controller 24 installed in the same room R1.

[0041] In Fig. 5, a signal sent from the first home appliance 7 (R1) is received by the first grandchild PLC modem 25 (R1). The signal received by the first grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in the room R1 via the first power line 4 (R1). The signal received by the child distribution board 20 is sent to the child PLC modem 23 (R1) via the first branch breaker 22 (R1) and the main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the second home appliance 7 (R1) via a local controller 24 (R1). The second home appliance 7 (R1) executes a process based on the received signal.

[0042] The signal path of the LAN communication illustrated in Fig. 5 allows communication with the second home appliance 7, which is not electrically connected to the grandchild PLC modem 25, by the local controller 24. Moreover, the signal amplified by the child PLC modem 23 is sent from the local controller 24 to the second home appliance 7 without passing through the second power line 4. The attenuation of the waveform of the signal received by the second home appliance 7 is thus further reduced.

[0043] Inter-Room LAN Communication

For example, the plurality of home appliances 7 installed in the different

rooms R1 and R3 are capable of performing LAN communication by signal paths of five aspects illustrated in Figs. 6 through 10.

[0044] First Aspect

Fig. 6 illustrates a signal path of LAN communication using one of the
5 grandchild PLC modems 25 installed in the room R1 and one of the grandchild PLC modems 25 installed in the room R3.

[0045] In Fig. 6, a signal sent from a home appliance 7 (R1) installed in the room R1 is received by a grandchild PLC modem 25 (R1). The signal received by the grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in
10 the room R1 via a power line 4 (R1). The signal received by the child distribution board 20 in the room R1 is sent to the child PLC modem 23 (R1) via a branch breaker 22 (R1) and the main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to a child distribution board 20 installed in the room R3 via the two transition-wired power
15 lines 15.

[0046] The signal sent to the child distribution board 20 in the room R3 is received by a child PLC modem 23 (R3). The child PLC modem 23 (R3) amplifies the received signal. The signal amplified by the child PLC modem 23 (R3) is sent to a grandchild PLC modem 25 (R3) via a main breaker 21 (R3), a branch breaker 22 (R3), and a power
20 line 4 (R3). The signal received by the grandchild PLC modem 25 (R3) is sent to a home appliance 7 (R3) installed in the room R3. The home appliance 7 (R3) executes a process based on the received signal.

[0047] The signal path of the LAN communication illustrated in Fig. 6 causes amplification of the signal sent from the home appliance 7 installed in the room R1
25 twice in total by the two child PLC modems 23 before and after passing through the two transition-wired power lines 15. The waveform of the signal attenuated over the course of the power line communication is thus reconstructed. Moreover, the breaker power lines 15 used for the power line communication has a large wire diameter and low impedance. The attenuation of the waveform of the signal passing through the two
30 power lines 15 is thus reduced. Accordingly, even when the signal path from the room R1 to the room R3 is long, the power line communication between the rooms R1 and R3 is stabilized.

[0048] Second Aspect

Fig. 7 illustrates a signal path of LAN communication using one of the
35 grandchild PLC modems 25 installed in the room R1 and one of the grandchild PLC modems 25 installed in the room R3, which passes through the child PLC modem 23 of

the child distribution board 20 installed in the room R2.

[0049] In Fig. 7, a signal sent from the home appliance 7 (R1) installed in the room R1 is received by the grandchild PLC modem 25 (R1). The signal received by the grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in the room R1 via the power line 4 (R1). The signal received by the child distribution board 20 in the room R1 is sent to the child PLC modem 23 (R1) via the branch breaker 22 (R1) and the main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the child distribution board 20 installed in the room R2 via the transition wired power line 15.

[0050] The signal sent to the child distribution board 20 in the room R2 is received by a child PLC modem 23 (R2). The child PLC modem 23 (R2) amplifies the received signal. The signal amplified by the child PLC modem 23 (R2) is sent to the child distribution board 20 installed in the room R3 via the transition wired power line 15.

[0051] The signal sent to the child distribution board 20 in the room R3 is received by the child PLC modem 23 (R3). The child PLC modem 23 (R3) amplifies the received signal. The signal amplified by the child PLC modem 23 (R3) is sent to the grandchild PLC modem 25 (R3) via the main breaker 21 (R3), the branch breaker 22 (R3), and the power line 4 (R3). The signal received by the grandchild PLC modem 25 (R3) is sent to the home appliance 7 (R3) installed in the room R3. The home appliance 7 (R3) executes a process based on the received signal.

[0052] The signal path of the LAN communication illustrated in Fig. 7 causes amplification of the signal sent from the home appliance 7 installed in the room R1 three times in total by the three child PLC modems 23 before, during, and after passing through the two transition-wired power lines 15. The waveform of the signal attenuated over the course of the power line communication is thus reconstructed better. Accordingly, even when the signal path from the room R1 to the room R3 is longer, the power line communication between the rooms R1 and R3 is stabilized.

[0053] Third Aspect

Fig. 8 illustrates a signal path of LAN communication using one of the grandchild PLC modems 25 installed in the room R1 and one of the grandchild PLC modems 25 installed in the room R3, which passes through the parent PLC modem 16 of the parent distribution board 10 installed in the living room L.

[0054] In Fig. 8, a signal sent from the home appliance 7 (R1) installed in the room R1 is received by the grandchild PLC modem 25 (R1). The signal received by the grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in

the room R1 via the power line 4 (R1). The signal received by the child distribution board 20 in the room R1 is sent to the child PLC modem 23 (R1) via the branch breaker 22 (R1) and the main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the parent distribution board 10 installed in the living room L via the power line 14.

[0055] The signal sent to the parent distribution board 10 in the living room L is received by a parent PLC modem 16 (L) via one of branch breakers 13 (L). The parent PLC modem 16 (L) amplifies the received signal. The signal amplified by the parent PLC modem 16 (L) is sent to the child distribution board 20 installed in the room R3 via the branch breaker 13 (L), the power line 14, and the transition wired power lines 15.

[0056] The signal sent to the child distribution board 20 in the room R3 is received by the child PLC modem 23 (R3). The child PLC modem 23 (R3) amplifies the received signal. The signal amplified by the child PLC modem 23 (R3) is sent to the grandchild PLC modem 25 (R3) via the main breaker 21 (R3), the branch breaker 22 (R3), and the power line 4 (R3). The signal received by the grandchild PLC modem 25 (R3) is sent to the home appliance 7 (R3) installed in the room R3. The home appliance 7 (R3) executes a process based on the received signal.

[0057] The signal path of the LAN communication illustrated in Fig. 8 causes amplification of the signal sent from the home appliance 7 installed in the room R1 three times in total by the child PLC modem 23 in the room R1, the parent PLC modem 16 in the living room L, and the child PLC modem 23 in the room R3 before and after passing through the two transition-wired power lines 15. The waveform of the signal attenuated over the course of the power line communication is thus reconstructed better. Accordingly, even when the signal path from the room R1 to the room R3 is longer, the power line communication between the rooms R1 and R3 is stabilized.

[0058] It should be noted that, in the signal path of the LAN communication illustrated in Fig. 8, the signal sent from the parent PLC modem 16 in the living room L is preferably amplified by the child PLC modem 23 in the room R2 while passing through the two transition-wired power lines 15. In the case of such a signal path, the signal sent from the home appliance 7 installed in the room R1 is amplified four times in total by the one parent PLC modem 16 and the three child PLC modems 23 before, during, and after passing through the two transition-wired power lines 15.

[0059] Fourth Aspect

Fig. 9 illustrates a signal path of LAN communication using one of the grandchild PLC modems 25 installed in the room R1 and the local controller 24 installed

in the room R3.

[0060] In Fig. 9, a signal sent from the home appliance 7 (R1) installed in the room R1 is received by the grandchild PLC modem 25 (R1). The signal received by the grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in the room R1 via the power line 4 (R1). The signal received by the child distribution board 20 in the room R1 is sent to the child PLC modem 23 (R1) via the branch breaker 22 (R1) and the main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the child distribution board 20 installed in the room R3 via the two transition-wired power lines 15.

[0061] The signal sent to the child distribution board 20 in the room R3 is received by the child PLC modem 23 (R3). The child PLC modem 23 (R3) amplifies the received signal. The signal amplified by the child PLC modem 23 (R3) is sent to one of the home appliances 7 (R3) installed in the room R3 via the local controller 24 (R3). The home appliance 7 (R3) executes a process based on the received signal.

[0062] The signal path of the LAN communication illustrated in Fig. 9 allows communication with the home appliance 7, which is not electrically connected to the grandchild PLC modem 25 in the room R3, by the local controller 24 installed in the room R3. Moreover, the signal amplified by the child PLC modem 23 installed in the room R3 is sent from the local controller 24 to the home appliance 7 without passing through the residential power line 4 with a small wire diameter in the room R3. The attenuation of the waveform of the signal received by the home appliance 7 in the room R3 is thus further reduced.

[0063] Fifth Aspect

Fig. 10 illustrates a signal path of LAN communication using the local controller 24 installed in the room R1 and the local controller 24 installed in the room R3.

[0064] In Fig. 10, one of the home appliances 7 (R1) installed in the room R1 sends a signal to the local controller 24 (R1) of the child distribution board 20 in the same room R1. The signal received by the local controller 24 (R1) is sent to the child PLC modem 23 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the child distribution board 20 installed in the room R3 via the two transition-wired power lines 15.

[0065] The signal sent to the child distribution board 20 in the room R3 is received by the child PLC modem 23 (R3). The child PLC modem 23 (R3) amplifies the received signal. The signal amplified by the child PLC modem 23 (R3) is sent to the

home appliance 7 (R3) installed in the room R3 via the local controller 24 (R3). The home appliance 7 (R3) executes a process based on the received signal.

[0066] The signal path of the LAN communication illustrated in Fig. 10 allows power line communication between the plurality of home appliances 7 installed in the different rooms R1 and R3 without using the residential power lines 4 with a small wire diameter. The attenuation of the waveform of the signal received by the home appliance 7 in the room R3 is thus further reduced.

[0067] Moreover, the signal path of the LAN communication illustrated in Fig. 10 allows power line communication between the plurality of home appliances 7 installed in the different rooms R1 and R3 via the two transition-wired power lines 15 even when the main breakers 21 and the branch breakers 22 of the child distribution boards 20 installed in the rooms R1, R2, and R3 are interrupted. That is, the child PLC modem 23 and the local controller 24 in each child distribution board 20 are electrically connected to the primary side of the main breaker 21. For this configuration, even when the main breaker 21 and the branch breaker 22 are interrupted, the signal paths of the power line communication between the plurality of home appliances 7 installed in the different rooms R1 and R3 are not broken.

[0068] 1.5.2 WAN Communication

For example, the plurality of home appliances 7 installed in the rooms R1, R2, and R3 are capable of performing WAN communication (Internet communication) by signal paths of two aspects illustrated in Figs. 11 and 12.

[0069] First Aspect

Fig. 11 illustrates a signal path of WAN communication using one of the grandchild PLC modems 25 installed in the room R1.

[0070] In Fig. 11, a signal sent from the home appliance 7 (R1) installed in the room R1 is received by the grandchild PLC modem 25 (R1). The signal received by the grandchild PLC modem 25 (R1) is sent to the child distribution board 20 installed in the room R1 via the power line 4 (R1). The signal received by the child distribution board 20 in the room R1 is sent to the child PLC modem 23 (R1) via the branch breaker 22 (R1) and the main breaker 21 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the parent distribution board 10 installed in the living room L via the power line 14.

[0071] The signal sent to the parent distribution board 10 in the living room L is received by the parent PLC modem 16 (L) via one of the branch breakers 13 (L). The parent PLC modem 16 (L) amplifies the received signal. The signal amplified by the parent PLC modem 16 (L) is sent to a broadband network gateway 17 (L). The

broadband network gateway 17 (L) converts the protocol of the received signal. The signal after protocol conversion is sent to, for example, the Internet network, such as an optical network.

[0072] Second Aspect

5 Fig. 12 illustrates a signal path of WAN communication using the local controller 24 of the child distribution board 20 installed in the room R1.

[0073] In Fig. 12, one of the home appliances 7 (R1) installed in the room R1 sends a signal to the local controller 24 (R1) of the child distribution board 20 in the same room R1. The signal received by the local controller 24 (R1) is sent to the child PLC
10 modem 23 (R1). The child PLC modem 23 (R1) amplifies the received signal. The signal amplified by the child PLC modem 23 (R1) is sent to the parent distribution board 10 installed in the living room L via the power line 14.

[0074] The signal sent to the parent distribution board 10 in the living room L is received by the parent PLC modem 16 (L) via the branch breakers 13 (L). The parent
15 PLC modem 16 (L) amplifies the received signal. The signal amplified by the parent PLC modem 16 (L) is sent to the broadband network gateway 17 (L). The broadband network gateway 17 (L) converts the protocol of the received signal. The signal after protocol conversion is sent to, for example, the Internet network, such as an optical network.

20 [0075] 2. Second Embodiment

Then, with reference to Fig. 13, a description is given to the second embodiment of a power line communication system including a distribution board of the present invention. It should be noted that, in the power line communication system illustrated in Fig. 13, identical reference signs are given to the same configurations as
25 in the first embodiment described above to omit the detailed description.

[0076] In Fig. 13, the power line communication system in the second embodiment is different from the first embodiment described above in the configuration of child distribution boards 20 installed in the respective rooms R1, R2, and R3. That is, a blocking filter 30 is electrically connected between the main breaker 21 and the branch
30 breakers 22 in each child distribution board 20. The blocking filter 30 has a function of blocking high frequencies more than a predetermined value. For example, the blocking filter 30 passes a current at 50 Hz or 60 Hz, which is the utility frequency in Japan, and blocks a high frequency signal at more than 50 Hz or 60 Hz.

[0077] In this situation, to the electrical outlets 5 installed in the respective rooms
35 R1, R2, and R3, the various home appliances 7 are electrically connected. These home appliances 7 generate high frequency noise. The high frequency noise is transmitted

to the child PLC modems 23 of the child distribution boards 20 installed in the respective rooms R1, R2, and R3 through the power lines 4 and 15. The blocking filters 30 block the transmission of the high frequency noise generated from the home appliances 7 to the child PLC modems 23. This prevents degradation of the signal sent and received between the different rooms R1, R2, and R3 and improves the communication quality of the power line communication.

[0078] It should be noted that, in the power line communication system in the present embodiment, the grandchild PLC modem 25 and the child PLC modem 23 installed in the same room R1, R2, or R3 are not capable of power line communication. This is because the signal (high frequency signal) sent and received between the grandchild PLC modem 25 and the child PLC modem 23 is blocked by the blocking filter 30. Accordingly, the power line communication system in the present embodiment performs LAN communication and WAN communication by signal paths described below.

[0079] For example, the plurality of home appliances 7 installed in the same room R1 perform LAN communication by the signal path illustrated in Fig. 3 using the two grandchild PLC modems 25 installed in the same room R1. The same applies to the rooms R2 and R3.

[0080] For example, the plurality of home appliances 7 installed in the different rooms R1 and R3 perform LAN communication by the signal path illustrated in Fig. 10 using the local controller 24 installed in the room R1 and the local controller 24 installed in the room R3. The same applies to other combinations of the rooms R1, R2, and R3.

[0081] For example, the plurality of home appliances 7 installed in the room R1 perform WAN communication by the signal path illustrated in Fig. 12 using the local controller 24 installed in the same room R1. The same applies to the rooms R2 and R3.

[0082] 3. Mode of Using Power Line Communication System

Then, modes of using the power line communication system in the present embodiment are specifically described.

[0083] 3.1 Usage for Nursing Senior Citizens, Patients, and the like

The power line communication system in the present embodiment is allowed to be used to nurse senior citizens, patients, and the like in the regular house illustrated in Fig. 2.

[0084] At least two of the rooms R1, R2, and R3 illustrated in Fig. 2 are used as private rooms respectively for a caregiver and a care receiver (senior citizen, patient, etc.). For example, the room R1 is used as a private room for a caregiver and the room R3 is used as a private room for a care receiver.

[0085] In the room R3 of the care receiver, as the plurality of home appliances 7, for example, various sensors to measure vital information (e.g., body temperature, blood pressure, pulse rate, SpO2, etc.) of the care receiver, a camera to monitor the condition of the care receiver, a microphone, a speaker, and a call signal transmitter to make contact with the care receiver, and the like are installed. These home appliances 7 are electrically connected to the grandchild PLC modems 25, the branch breakers 22 of the child distribution board 20, or the local controller 24 installed in the room R3.

[0086] In the room R1 of the caregiver, the home appliance 7 capable of receiving and processing the vital information, an image signal, an audio signal, and a call signal sent from the home appliances 7 of the care receiver are installed. Examples of such a home appliance 7 include personal computers and smartphones. Such a personal computer or a smartphone is electrically connected to one of the grandchild PLC modems 25 or the local controller 24 of the child distribution board 20 installed in the room R1.

[0087] The home appliances 7 installed in the room R1 of the caregiver and the home appliance 7 installed in the room R3 of the care receiver perform LAN communication by any of the signal paths illustrated in Figs. 6 through 10. The caregiver in the room R1 can manage the health status of the care receiver in the room R3 and talk with the care receiver with a display, a microphone, and a speaker of the personal computer or the smartphone.

[0088] It should be noted that the home appliances 7 installed in the room R3 of the care receiver are also capable of performing power line communication with the home appliances 7 installed in the room R2 and the living room L, not limited to those in the room R1. It is thus possible to share the information of the care receiver, who is in the room R3, in all of the rooms R1 and R2 and the living room L.

[0089] 3.2 Use as Alarm

The power line communication system in the present embodiment is allowed to be used as an alarm to inform residents of an abnormal event occurred in the regular house illustrated in Fig. 2.

[0090] In the living room L, the rooms R1, R2, and R3, and other locations in the regular house illustrated in Fig. 2, multiple types of sensors (home appliances 7) are installed. Examples of the multiple types of sensors include a motion sensor, a fire alarm, the call signal transmitter described above used by the care receiver, and the like. Meanwhile, the parent PLC modem 16 of the parent distribution board 10 installed in the living room L and the child PLC modems 23 installed in the respective rooms R1, R2, and R3 are provided with a function of classifying the received signal.

[0091] A signal to inform of a highly urgent abnormal event, for example, a detected signal of a fire alarm is received by the parent PLC modem 16 and all the child PLC modems 23 and sent to the home appliances 7 installed respectively in the living room L and the rooms R1, R2, and R3. The residents in all rooms are thus notified of occurrence of fire.

[0092] A signal to inform of a less urgent abnormal event, for example, a detected signal of a motion sensor is received by the parent PLC modem 16 and all the child PLC modems 23 but only the parent PLC modem 16 sends the detected signal to the home appliances 7 installed in the living room L. Only the residents in the living room L are thus notified of a visitor.

[0093] A signal to inform a specific resident of an abnormal event, for example, a call signal of a transmitter used by the care receiver is received by the parent PLC modem 16 and all the child PLC modems 23 but only the child PLC modem 23 installed in the room R1 where the caregiver is sends the call signal to the corresponding home appliance 7 installed in the same room R1. Only the caregiver in the room R1 is thus notified of a call from the care receiver.

[0094] 3.3 Application to Multifamily Dwelling and the like

The power line communication system in the present embodiment is applicable to a building manager room and a plurality of dwelling units of a multifamily dwelling (apartment building) illustrated in Fig. 14.

[0095] The multifamily dwelling illustrated in Fig. 14 includes one building manager room M and four dwelling units D1, D2, D3, and D4. In the building manager room M, a parent distribution board 10 is installed. Each of the dwelling units D1 and D2 has three rooms R1, R2, and R3. Each of the dwelling units D3 and D4 has two rooms R1 and R2. In each of the rooms R1, R2, and R3, a child distribution board 20 is installed.

[0096] The three child distribution boards 20 installed in each of the dwelling units D1 and D2 are transition wired by two power lines 15. One of the three transition-wired child distribution boards 20 is electrically connected to one of branch breakers 13 of the parent distribution board 10 installed in the building manager room M by one power line 14. Meanwhile, the two child distribution boards 20 installed in each of the dwelling units D3 and D4 are transition wired by one power line 15. One of the two transition-wired child distribution boards 20 is electrically connected to one of the branch breakers 13 of the parent distribution board 10 installed in the building manager room M by one power line 14.

[0097] For example, a plurality of home appliances 7 installed in the same room R1

of the one dwelling unit D1 perform LAN communication by the one child distribution board 20 installed in the room R1. In addition, a plurality of home appliances 7 installed in the different rooms R1, R2, and R3 of the one dwelling unit D1 perform LAN communication by the three child distribution boards 20 installed in the rooms R1, R2, and R3. The same applies to the dwelling units D2, D3, and D4.

[0098] For example, the parent distribution board 10 installed in the building manager room M and the plurality of child distribution boards 20 installed in the dwelling units D1, D2, D3, and D4 may be configured not to allow power line communication via the power lines 14. For example, the child distribution boards 20 are configured to have a function of classifying received signals not to send some of the signals from the child distribution boards 20 to the parent distribution board 10. The restrictions on power line communication between the parent distribution board 10 and the child distribution boards 20 allow improvement of information security in LAN communication in the dwelling units D1, D2, D3, and D4.

[0099] On the contrary, the parent distribution board 10 installed in the building manager room M and the child distribution boards 20 installed in the dwelling units D1, D2, D3, and D4 may be configured to allow power line communication via the power lines 14. By allowing the power line communication between the parent distribution board 10 and the child distribution boards 20, it is possible to collectively manage information of the dwelling units D1, D2, D3, and D4 in the building manager room M. For example, amounts of power consumption in the dwelling units D1, D2, D3, and D4 may be collectively managed with measuring devices installed in the building manager room M.

[0100] For example, power line communication via the parent distribution board 10 may be allowed between the plurality of child distribution boards 20 installed in the dwelling units D1, D2, D3, and D4. For example, when members of the same household live in the dwelling units D1 and D2, it is convenient to perform power line communication between the child distribution boards 20 installed in the dwelling units D1 and D2. In this case, the parent distribution board 10 installed in the building manager room M and the child distribution boards 20 installed in the dwelling units D1 and D2 may be configured to allow power line communication via the power lines 14.

[0101] The power line communication via the parent distribution board 10 between the plurality of child distribution boards 20 installed in the dwelling units D1, D2, D3, and D4 in such a manner means to share the one parent PLC modem 16 between the plurality of dwelling units. That is, a signal sent and received between the child distribution boards 20 installed in the plurality of dwelling units is amplified by the

parent PLC modem 16 in the parent distribution board 10. As a result, the power line communication between the dwelling units is stabilized and the communication quality is improved.

[0102] It should be noted that the power line communication system in the present embodiment is applicable to, for example, office buildings not limited to multifamily dwellings as described above. The power line communication system in the present embodiment allows the same power line communication as the above description between a plurality of business machines installed on a plurality of floors and in a plurality of rooms of such an office building.

[0103] 4. Technical Effects of Power Line Communication System in Present Embodiments

The power line communication systems in the present embodiments described above exhibit the following technical effects.

[0104] The waveform of a signal sent from one of the home appliances 7 is attenuated by the wire diameter of the power lines 4, 14, and 15, the length of the signal path, the influence of the home appliances 7, and the like. According to the power line communication systems in the present embodiments, the attenuated signal waveform is reconstructed by the amplification mechanisms of the one or more child PLC modems 23 and/or the parent PLC modem 16. For this configuration, the power line communication between the plurality of home appliances 7 is stabilized and the communication quality is improved.

[0105] The power line communication systems in the present embodiments have a configuration where the child PLC modem 23 is electrically connected to the primary side of the main breaker 21 in each child distribution board 20 and the local controller 24 is electrically connected to the secondary side of the child PLC modem 23. This configuration allows power line communication using two of the local controllers 24 even when the main breaker 21 and the branch breakers 22 in the child distribution board 20 are interrupted. In this case, it is possible to perform power line communication using the distribution board power lines 14 and 15 with a large wire diameter without using the residential power lines 4 with a small wire diameter. As a result, attenuation of the signal waveform is reduced even more.

Description of Reference Numerals

[0106]

- | | | |
|----|---|--|
| 35 | 1 | Distribution board (technique in the past) |
| | 2 | Main Breaker |

	3	Branch Breaker
	4	Power Line
	5	Electrical Outlet
	6	PLC Modem
5	7	Home Appliance
	8	Bus
	10	Parent Distribution board (Present Invention)
	11	Main Breaker
	12	Bus
10	13	Branch Breaker
	14	Power Line
	15	Power Line
	16	Parent PLC Modem
	17	Broadband Network Gateway
15	18	Local Controller
	19	Air Conditioner
	20	Child Distribution board (Present Invention)
	21	Main Breaker
	22	Branch Breaker
20	23	Child PLC Modem
	24	Local Controller
	25	Grandchild PLC Modem
	30	Blocking Filter

CLAIMS

1. A distribution board comprising: a main breaker; a bus; and a plurality of branch breakers, each of the plurality of branch breakers electrically connected to a secondary side of the main breaker via the bus, wherein
5 the distribution board further includes a PLC modem electrically connected to a primary side of the main breaker or, via the bus, the secondary side of the main breaker and a primary side of the branch breakers, and the PLC modem is configured to amplify a received signal and send the signal via a power line.
- 10 2. A power line communication system, comprising a plurality of distribution boards electrically connected via at least one power line, each of the plurality of distribution boards including a main breaker, a bus, and a plurality of branch breakers, and each of the plurality of branch breakers electrically connected to a secondary side of the main breaker via the bus, wherein
15 each of the distribution boards further includes a PLC modem electrically connected to a primary side of the main breaker or, via the bus, the secondary side of the main breaker and a primary side of the branch breakers, and the PLC modem is configured to amplify a received signal and send the signal, and
the signal sent from one of the PLC modems is received by another of the PLC
20 modems via the power line.
3. The power line communication system according to Claim 2, wherein the primary side of the main breaker in each of the distribution boards is serially connected by the power line.
4. The power line communication system according to Claim 2 or 3, comprising
25 at least three of the distribution boards, wherein
the PLC modem in any one of the distribution boards is configured to relay sending and receiving of the signal between the PLC modems in other two of the distribution boards.
5. The power line communication system according to any one of Claims 2
30 through 4, wherein the PLC modem in each of the distribution boards is electrically connected to the primary side of the main breaker.
6. The power line communication system according to any one of Claims 2 through 5, wherein the PLC modem in each of the distribution boards receives the signal via any one of the branch breakers.
- 35 7. A power line communication system, comprising: at least one parent distribution board and a plurality of child distribution boards, the parent and child

distribution boards being electrically connected via a plurality of power lines, each of the parent and child distribution boards including a main breaker, a bus, and a plurality of branch breakers, each of the branch breakers being electrically connected to a secondary side of the main breaker via the bus, a primary side of the main breaker in the parent
5 distribution board being electrically connected to an incoming line of power, and a secondary side of at least one of the branch breakers in the parent distribution board being electrically connected to a primary side of at least one of the main breakers in the child distribution boards via the respective power lines, wherein

the parent distribution board further includes a parent PLC modem electrically
10 connected to the secondary side of the main breaker and a primary side of the branch breakers via the bus,

each of the child distribution boards further includes a child PLC modem electrically connected to the primary side of the main breaker,

the child PLC modems are configured to receive a signal via at least one of the
15 branch breakers in the child distribution boards, amplify the signal, and send the signal via the respective power lines, and

the parent PLC modem is configured to receive the signal via the respective power lines, amplify the signal, and send the signal.

8. The power line communication system according to Claim 7, comprising at
20 least two of the child distribution boards, wherein

the parent PLC modem is configured to relay sending and receiving of the signal between the child PLC modems in two of the child distribution boards.