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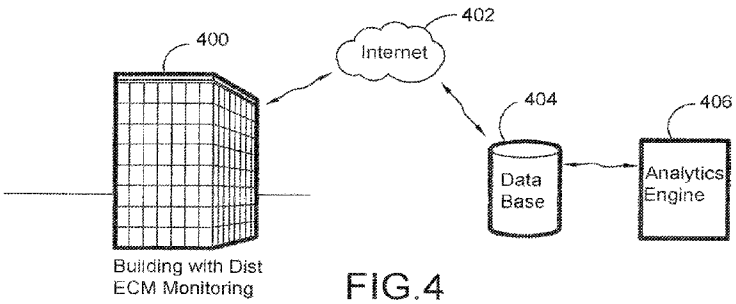

FIG.4

(57) Abstract: ECM monitoring device for one or more energy consuming devices that includes a sensor module for sensing one or more ambient conditions and/or one or more pre-existing operating parameters of the one or more energy consuming devices, a computational module in communication with the sensor module to calculate one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices based on output from the sensor module, and a communication module to transmit one or more updated operating parameters to the one or more energy consuming devices.

DEVICES, METHODS, AND SYSTEMS FOR MONITORING DISTRIBUTED ENERGY CONSERVATION MEASURES

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefit of U.S. Provisional Application No. 61/619,051, filed April 2, 2012, the entirety of which is hereby incorporated by reference.

FIELD

[0002] The present disclosure relates to energy conservation. More particularly, the present disclosure relates to devices, methods, and systems for monitoring and analyzing the effectiveness, savings and performance of Energy Conservation Measures (ECMs).

BACKGROUND

[0003] An Energy Conservation Measure (ECM) refers to any modification or improvement performed or deployed to save, or optimize the use of energy. Examples of ECMs may include, without limitation, retrofitting incandescent lights with Compact Fluorescent Lamps (CFL) or Light Emitting Diode (LED) lights, replacing a water heater with a tank-less water heater, weatherization efforts including but not limited to window replacements, caulking and sealing, and the like. Such ECMs may be deployed in a few locations or distributed among many locations within a floor of a building, among multiple buildings, and multiple geographies.

[0004] Plug-level load monitoring devices are currently available for providing a user with information about how much energy an appliance or a device plugged into a special

outlet is consuming. Such devices typically have a localized display and monitor only appliances plugged into that outlet.

[0005] The prior art, however, provides no direct method for measuring the impact of ECMs and/or identifying the contributions of ECMs to energy savings, without the corruption of data by external factors such as weather, human behavior, and many other factors that can have an impact on the ECMs and their contribution.

[0006] Accordingly, a method is needed for easily measuring the impact of ECMs and/or identifying the contributions of ECMs to energy savings, without the corruption of data by external factors.

SUMMARY OF THE INVENTION

[0007] One embodiment of the present invention provides an ECM monitoring device for one or more energy consuming devices. The ECM monitoring device for one or more energy consuming devices can include a sensor module for sensing one or more ambient conditions and/or one or more pre-existing operating parameters of the one or more energy consuming devices, a computational module in communication with the sensor module to calculate one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices based on output from the sensor module, and a communication module to transmit one or more updated operating parameters to the one or more energy consuming devices.

[0008] In one embodiment, the one or more energy consuming devices are connected to a power supply capable of supplying varying levels of voltage and/or current to the one or more energy consuming devices. The power supply can be communicatively coupled to

the communication module. In one embodiment, the communication module includes a power line communication module to transmit updated operating parameters to the power supply based at least in part on ambient conditions of the one or more energy consuming devices as determined by the sensor module. In one embodiment, the communication module reduces the voltage and/or current transmitted by the power supply to the one or more energy consuming devices.

[0009] The computational module can include an analytics and recommendation engine, optionally communicatively coupled with a database, to compare calculated values of one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices to previously observed and/or expected values. The one or more updated operating parameters can be based, at least in part, on output from the analytics and recommendation engine. The analytics and recommendation engine and the database can be located in one or more remotely located central stations. Alternatively, in one embodiment, the ECM monitoring device is integrated into the one or more energy consuming devices.

[0010] In one embodiment, the communication module includes a wireless communication module to communicate with the one or more energy consuming devices wirelessly. In one embodiment, the wireless communication module broadcasts a first electronic serial number (ESN) associated with the ECM monitoring device to a node or gateway associated with the one or more energy consuming devices, if the first ESN is recognized by the node or gateway associated with the one or more energy consuming devices, the node or gateway transmits to the wireless communication module a second electronic serial number (ESN) associated with the one or more energy consuming

devices, if the second ESN is recognized by the wireless communication module, the wireless communication module broadcasts the one or more updated operating parameters to the node or gateway associated with the or more energy consuming devices, if the node or gateway associated with the one or more energy consuming devices receives the updated operating parameters, the node or gateway broadcasts registration data at specific intervals or when requested by the wireless communication module, and if the wireless communication module receives and recognizes said registration data, the wireless communication module broadcasts data packets containing data obtained by the sensor module and processed by the computation module to the one or more energy consuming devices.

[0011] In one embodiment, the updated operating parameters are based, at least in part, on a comparison of ambient conditions obtained by the sensor module to previously observed and/or expected values of said ambient conditions. Alternatively, or in addition, the comparison of the calculated values of energy consumption, power factor, run time and time to end-of-life to previously observed and/or expected values occurs in one or more remotely located central stations.

[0012] Yet another embodiment of the present application provides a method of monitoring one or more energy consuming devices that includes, sensing via a sensor module one or more ambient conditions and/or one or more pre-existing operating parameters of the one or more energy consuming devices, calculating one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices based on output from the sensor module, and transmitting via a communication module updated operating parameters to the one or more energy

consuming devices based at least in part on a comparison of said calculated values of energy consumption, power factor, run time and time to end-of-life to previously observed and/or expected values.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Fig. 1 is a depiction of an ECM monitoring device for an LED light assembly according to a non-limiting embodiment of the present application.

[0014] Fig. 2A is a depiction of ECM monitoring device integrated into an energy consuming device; Fig. 2B depicts communication of power consumption related parameters sent over a power line; and Fig2C depicts a wireless method of communication (e.g. low power blue tooth, zigbee or other protocols), self-discovering neighboring devices and nodes, and a self-configuring network.

[0015] Fig. 3 a method that may be used by a newly installed ECM to self-configure itself into a network according to an exemplary embodiment of the present disclosure.

[0016] Fig. 4 is a depiction of a remotely located central station, which may include a database and an analytics and recommendation engine communicatively coupled to the database.

[0017] Fig. 5 depicts output of an analytics engine according to an illustrative embodiment of the present application.

DETAILED DESCRIPTION

[0018] An ECM monitoring device is disclosed herein for monitoring at least one of the energy usage or consumption, of an ECM, the power factor or quality of energy of the ECM, time of use or run-time of the ECM, the time to end-of-life of the ECM, and any other energy and performance characteristics of the ECM. In some embodiments, the monitoring data can be used for determining the effectiveness of the ECM, the energy savings contributed by the ECM, and the performance parameters of the ECM by comparing the data against expected results, and the like. The ECM may comprise, without limitation, a lighting fixture, an appliance, a weatherization effort, and the like. The ECM may be a new ECM or an ECM currently deployed, or a non-ECM energy consuming appliances.

[0019] In some embodiments, the ECM monitoring device may reside in a lighting fixture or appliance. In other embodiments the ECM monitoring device may be built or integrated into the lighting fixture or appliance. In some embodiments, the ECM monitoring device may transmit ECM energy and performance data to a central station, such as a database/server. This data may be used to continuously analyze or further analyze the consumption of the light fixture or appliance. In some embodiments, the results of the analysis may be made available to the user via a web browser or used locally by the ECM to make autonomous decisions including but not limited to adjusting: the energy consumption of the ECM, the power factor (quality of the energy) of the ECM, and run time of the ECM.

[0020] FIG. 1 is a block diagram of an ECM monitoring device, according to an exemplary embodiment of the present disclosure. For the purpose of illustration only, and not limitation, the ECM monitoring device will be described with reference to an LED lighting assembly 10 comprising, for example, an array of LEDs 12. The LED array 12 may be electrically connected to a driver (power supply) 14 which supplies voltage and current that matches the electrical characteristics of LED array 12. The driver 14 may be capable of dimming the LED array 12 using conventional methods such as pulse width modulation. The ECM monitoring device, denoted generally by reference numeral 20, may comprise a sensor module 22, a computation module 24, a communication module 26, a power line communication module 28, and a wireless communication module 30.

[0021] The sensor module 22 may be electrically connected to the driver 14 of the LED lighting assembly 10 and the power line communication module 26. The sensor module 22 may comprise one or more sensing elements for sensing at least one of the energy consumption, power factor, and run-time of the LED lighting assembly 10. In some embodiments, the sensor module 22 may also comprise one or more sensing elements for sensing the ambient conditions of the LED lighting assembly including, without limitation, temperature, humidity, illumination, and the like.

[0022] The computation module 24 may be communicatively coupled to the driver 14 of the LED lighting assembly 10, the sensor module 22 and the communication module 26. The communication module 26 may also be communicatively coupled to the power line communication module 28 and the wireless communication module 30. The computation module 24 and the communication modules 26, 28, and 30, may be implemented in hardware, software, or hardware and software. The modules may contain

one or more memory storage areas, such as RAM, for storage of data and instructions for performing processing operations, and one or more processors for executing data processing instructions and processing data, in accordance with the present disclosure. Alternatively, instructions for performing processing operations can be stored in hardware in one or more memories.

[0023] The computation module 24 may communicate with sensor module 22 to obtain various electrical operating parameters of the LED light assembly 10 and/or ambient conditions and use such data to calculate one or more of the energy consumption, power factor, run time, and time to end-of-life of the LED lighting assembly 10. In some embodiments, the computation module 24 may include an analytics and recommendation engine that compares the calculated energy consumption, power factor, run time, and time to end-of-life of the LED lighting assembly 10 against expected results and, if necessary, causes the driver 14 of the LED lighting assembly 10 to make certain adjustments to one or more of the energy consumption, the power factor, and run time, of the LED lighting assembly 10 to optimize the assembly's energy consumption and performance, thereby allowing the ECM monitoring device 20 to autonomously control the LED lighting assembly 10. For example and not limitation, the computation module 24 may cause the driver 14 of the LED lighting assembly to reduce power consumption based on local conditions such as temperature, humidity, illumination, occupancy, and/or the like.

[0024] The communication modules 26, 28, 30 of the ECM monitoring device 20 allow the device 20 to network and communicate with other ECMs appropriately equipped with ECM monitoring devices 20. The other ECMs may be similar or identical

LED lighting assemblies as shown in FIG. 2A, dissimilar LED lighting assemblies (ECM or non-ECM), other appliances (ECM or non-ECM), weatherization efforts, and any combination thereof. The ECMs with their corresponding ECM monitoring devices, may be located anywhere including, without limitation, in the same room, in different rooms, on the same floor of a building, on different floors of a building, in different buildings, and the like. The power line communication module 28 of the ECM monitoring device 20 may include one or more different types of power line communication technology, which enable the ECM to communicate (receive and transmit) with other devices over a power line. The wireless communication module 30 of the ECM monitoring device 20 may include one or more different types of low power wireless communication technology, which enable the ECM to wirelessly communicate (receive and transmit) with other devices. The low power wireless technologies may include, without limitation, low power wireless technologies constructed under the Zigbee™ standard, the Bluetooth® standard, and any other suitable low power wireless communication technology. Depending upon the application and circumstances, the communication module 26 may select one or both of the power line communication module 28 and wireless communication module 30, for enabling the ECM to communicate with other devices.

[0025] The embodiment of FIG. 2B illustrates a plurality of LED lighting assemblies 100 electrically connected to one another by jumper power lines 102 and each equipped with an ECM monitoring device. The electrically interconnected LED lighting assemblies 100 may also be connected to a main power line 104 that communicates directly or indirectly with a central station (not shown), such as database/server. Because the LED lighting assemblies 100 are electrically connected to one another by jumper

power lines 102, the communication modules of their ECM monitoring devices may select their corresponding power line communication modules which enable the assemblies 100 to communicate with one another over the power lines 102 and to transmit collected power consumption and related parameter data over a primary power line 104 to the central station.

[0026] The embodiment of FIG. 2C illustrates a plurality of LED lighting assemblies 200 each equipped with an ECM monitoring device. Because the LED lighting assemblies 200 are not electrically connected to one another by jumper power lines as in FIG. 2B, the communication modules of their ECM monitoring devices may select their corresponding wireless communication modules, which enables the assemblies 200 to communicate wirelessly with one another and/or with a gateway over a wireless communication network. The gateway may further communicate collected power consumption and related parameters data back to a central station via, for example but not limitation, the internet or a Wide Area Network (WAN).

[0027] In some embodiments, the communication module 26 of the ECM monitoring device 20 may also be capable of self-configuring, thereby allowing plural ECMs equipped with ECM monitoring devices 20 to form a network. The self-configuring network capability creates a path for all the ECMs distributed in a building, geographically across multiple buildings, and in different parts of the world, to communicate to a central monitoring facility. The network may have any desired topology including, without limitation, star and random mesh topologies. The network of plural ECMs will allow each ECM to be accessible from a gateway or plural gateways to communicate energy, performance parameter, ambient condition and other data. In the

event of a communications link failure or prior to establishing a communications link, the ECM monitoring devices are capable of storing the data gathered from their corresponding ECMs.

[0028] FIG. 3 illustrates a method that may be used by a newly installed ECM to self-configure itself into a network according to an exemplary embodiment of the present disclosure. Once the ECM has been installed and powered on, the communication module of the ECM monitoring device causes the wireless communication module to broadcast the ECM's electronic serial number (ESN) at 300. If the node or gateway receives and recognizes the ECM's ESN, the node or gateway broadcasts its ESN at 302. If the wireless communication module of the ECM receives and recognizes the node or gateway's broadcasted ESN, the ECM's communication module causes the wireless communication module to broadcast the ECM's parameters (e.g., wattage, type, etc.) at 304. If the node or gateway receives the ECM's parameters, the node or gateway broadcasts registration data at specific intervals or when requested by the ECM at 306. If the wireless communication module of the ECM receives and recognizes the node or gateway's broadcasted reg. data, the ECM's communication module causes the wireless communication module to broadcast data packets (containing data obtained by the sensor module and processed by the computation module of the ECM monitoring device) at 308. The ECM's wireless communication module will re-broadcast the data packet at 308 until the node or gateway broadcasts an acknowledgement at 310 and the ECM's wireless communication module receives the acknowledgement.

[0029] In some embodiments, as depicted in FIG. 4, a remotely located central station may be provided, which may include a database 404 and an analytics and

recommendation engine 406 communicatively coupled to the database 404. The central station may communicate over the internet 402 with the plural ECMs distributed in a building 400, via their ECM monitoring devices, to obtain energy, performance parameter, and ambient data. The communication may take place on a regular basis either timed or be interrupt-driven.

[0030] Once the data is received, the analytics and recommendation engine 406, similar to the one described earlier with respect to the ECM monitoring device, may perform analytics on conditions that existed earlier to the present conditions, etc., and then provide actionable recommendations to a user, without any further analysis required on the part of the user. More specifically, the results of the analytics may be presented in a graphical or numerical form to provide the user with a quick recommendation. These recommendations may include without limitation what the resource consumption levels are, how they are performing against goals, and what could be done to optimize the use of resources, to name a few. As shown in FIG. 5, in some embodiments, the central station may display energy savings due to deployment of ECMs enabled with the ECM monitoring device, by city on a map 500. The central station may also provide operations and maintenance alerts including but not limited to device failure alerts, device malfunction alerts, and device end-of-life alerts.

[0031] The analytics and recommendation (AR) engine 406 of the central system may include two operational modes: 1) a local mode or autonomous mode, and 2) a central mode. At any given time, the AR engine may operate in either one of the two modes or both modes concurrently.

[0032] In the autonomous mode, as described earlier, the ECMs enabled with the ECM monitoring device can act on information gained to make local decisions in the absence of a communication link or by design. Such examples may include without limitation, reducing power consumption based on local conditions such as temperature, humidity, illumination, occupancy, and the like.

[0033] In the centralized mode, data gathered by the ECM monitoring devices is sent to the central station for storage and analysis. The storage can be persistent or transient depending on the needs of the application. In this mode, the data is analyzed for trends, performance against specific targets / goals, resource consumption against external variables, and the like.

[0034] The central station may be implemented in software, hardware, or hardware and software. In addition, the central station may contain one or more memory storage areas, such as RAM, for storage of data (database 404) and instructions for performing processing operations, and one or more processors for executing data processing instructions and processing data, in accordance with the present disclosure. Alternatively, instructions for performing processing operations can be stored in hardware.

CLAIMS

1. An ECM monitoring device for one or more energy consuming devices comprising:

(a) a sensor module for sensing one or more ambient conditions and/or one or more pre-existing operating parameters of the one or more energy consuming devices;

(b) a computational module in communication with the sensor module to calculate one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices based on output from the sensor module; and

(c) a communication module to transmit one or more updated operating parameters to the one or more energy consuming devices.

2. The ECM monitoring device of claim 1, wherein the one or more energy consuming devices are connected to a power supply capable of supplying varying levels of voltage and/or current to the one or more energy consuming devices, the power supply communicatively coupled to the communication module.

3. The ECM monitoring device of claim 2, wherein the computational module includes an analytics and recommendation engine, optionally communicatively coupled with a database, to compare calculated values of one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices to previously observed and/or expected values, and wherein the one or more updated operating parameters are based at least in part on output from the analytics and recommendation engine.

4. The ECM monitoring device of claim 3, wherein the analytics and recommendation engine and the database are located in one or more remotely located central stations.

5. The ECM monitoring device of claim 1, wherein the ECM monitoring device is integrated into the one or more energy consuming devices.

6. The ECM monitoring device of claim 2, wherein the communication module includes a power line communication module to transmit updated operating parameters to the power supply based at least in part on ambient conditions of the one or more energy consuming devices as determined by the sensor module.

7. The ECM monitoring device of claim 6, wherein the communication module reduces the voltage and/or current transmitted by the power supply to the one or more energy consuming devices.

8. The ECM monitoring device of claim 1, wherein the communication module includes a wireless communication module to communicate with the one or more energy consuming devices wirelessly.

9. The ECM monitoring device of claim 8, wherein:

(a) the wireless communication module broadcasts a first electronic serial number (ESN) associated with the ECM monitoring device to a node or gateway associated with the one or more energy consuming devices;

(b) if the first ESN is recognized by the node or gateway associated with the one or more energy consuming devices, the node or gateway transmits to the wireless communication module a second electronic serial number (ESN) associated with the one or more energy consuming devices;

(c) if the second ESN is recognized by the wireless communication module, the wireless communication module broadcasts the one or more updated operating parameters to the node or gateway associated with the or more energy consuming devices;

(d) if the node or gateway associated with the one or more energy consuming devices receives the updated operating parameters, the node or gateway broadcasts registration data at specific intervals or when requested by the wireless

communication module; and

(e) if the wireless communication module receives and recognizes said registration data, the wireless communication module broadcasts data packets containing data obtained by the sensor module and processed by the computation module to the one or more energy consuming devices.

10. A method of monitoring one or more energy consuming devices comprising:

(a) sensing via a sensor module one or more ambient conditions and/or one or more pre-existing operating parameters of the one or more energy consuming devices;

(b) calculating one or more of energy consumption, power factor, run time and time to end-of-life of the one or more energy consuming devices based on output from the sensor module; and

(c) transmitting via a communication module updated operating parameters to the one or more energy consuming devices based at least in part on a comparison of said calculated values of energy consumption, power factor, run time and time to end-of-life to previously observed and/or expected values.

11. The method of monitoring one or more energy consuming devices of claim 10, wherein the one or more energy consuming devices are connected to a power supply capable of supplying varying levels of voltage and/or current to the one or more energy consuming devices, the power supply communicatively coupled to the communication module.

12. The method of monitoring one or more energy consuming devices of claim 11, wherein the updated operating parameters are based at least in part on a comparison of ambient conditions obtained by the sensor module to previously observed and/or expected values of said ambient conditions.

13. The method of monitoring one or more energy consuming devices of claim 10, wherein the comparison of said calculated values of energy consumption, power factor, run time and time to end-of-life to previously observed and/or expected values occurs in one or more remotely located central stations.

14. The method of monitoring one or more energy consuming devices of claim 10, wherein the communication module includes a wireless communication module to communicate with the one or more energy consuming devices wirelessly.

15. The method of monitoring one or more energy consuming devices of claim 14, further comprising:

(a) broadcasting via the wireless communication module a first electronic serial number (ESN) associated with the ECM monitoring device to a node or gateway associated with the one or more energy consuming devices;

(b) recognizing the first ESN by the node or gateway associated with the one or more energy consuming devices;

(c) transmitting from the node or gateway associated with the one or more energy consuming devices to the wireless communication module a second electronic serial number (ESN) associated with the one or more energy consuming devices;

(d) recognizing the second ESN by the wireless communication module;

(e) broadcasting via the wireless communication module the one or more updated operating parameters to the node or gateway associated with the one or more energy consuming devices;

(f) receiving the one or more updated operating parameters at the node or gateway associated with the one or more energy consuming devices;

(g) broadcasting to the wireless communication module registration data from the node or gateway associated with the one or more energy consuming devices at specific intervals or when requested by the wireless communication module;

(h) recognizing the registration data received by the wireless communication module; and

(i) broadcasting data packets containing data obtained by the sensor module and data processed by the computational module to the one or more energy consuming devices.

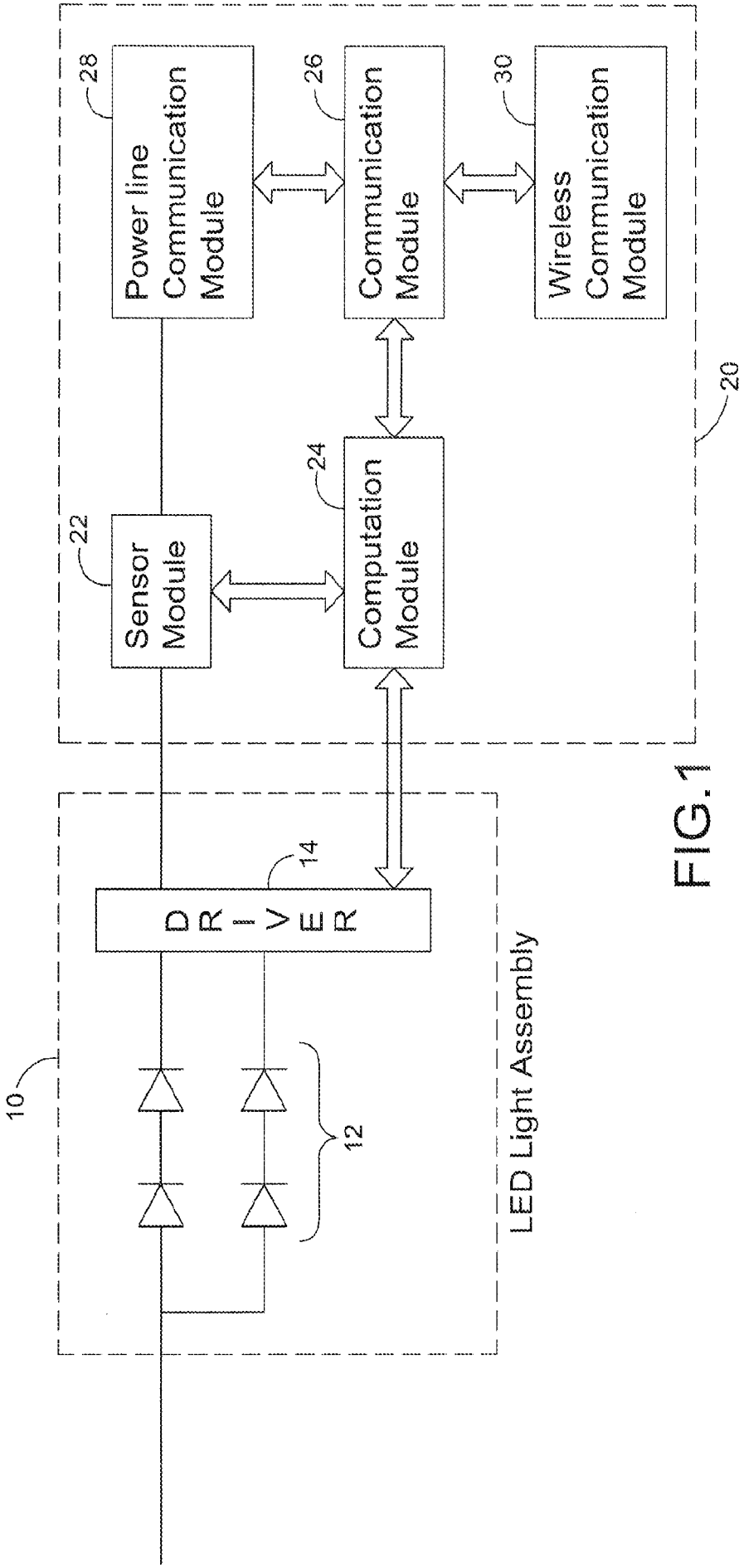
28
Power line Communication Module
26
Communication Module
30
Wireless Communication Module
20
24
Computation Module
22
Sensor Module
14
DRIVER
10
12
LED Light Assembly

FIG.1

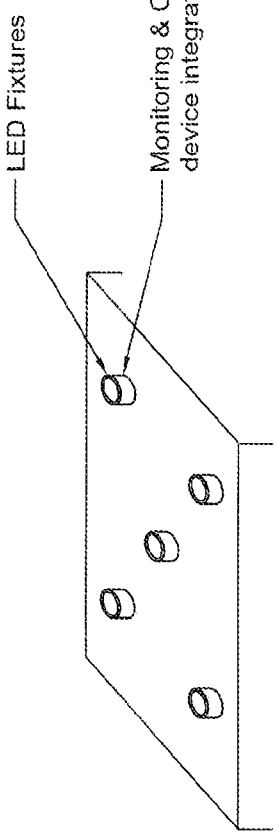

FIG.2A

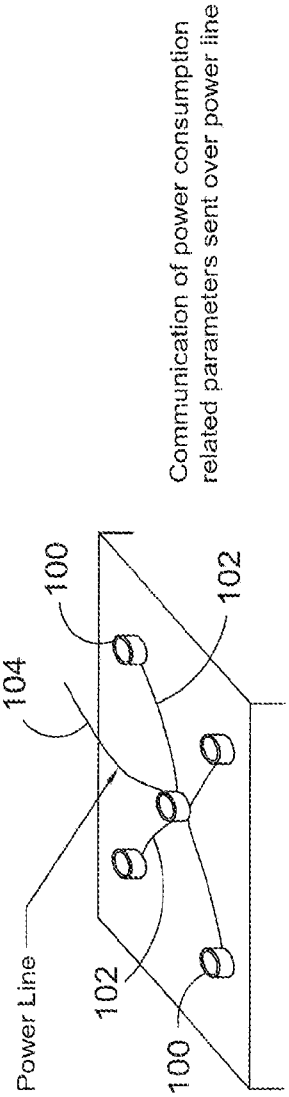

FIG.2B

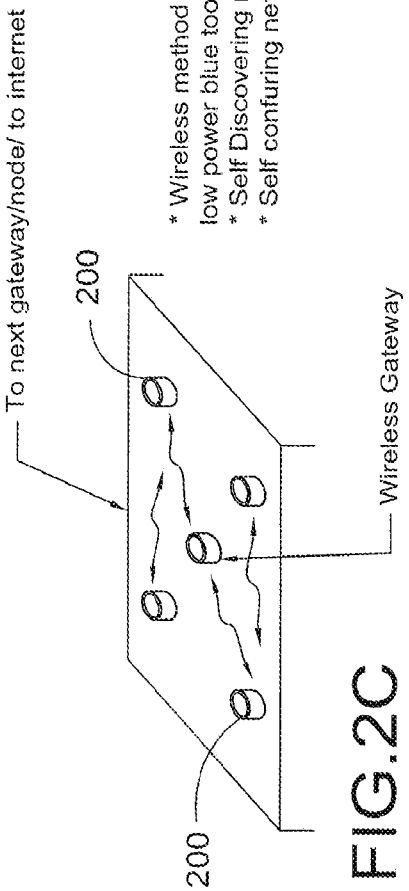

FIG.2C

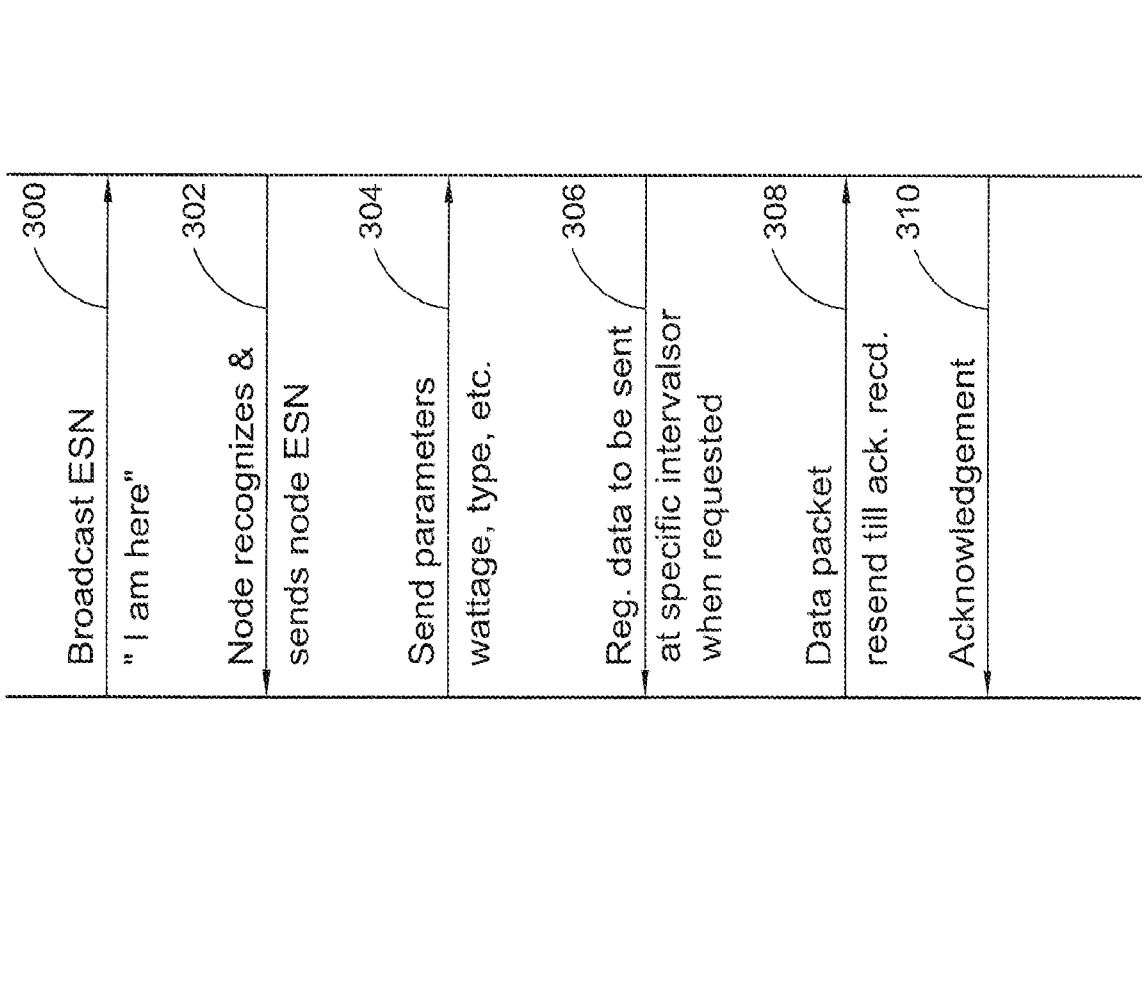
New device installed & powered on
Node/Gateway
300
Broadcast ESN
" I am here"
302
Node recognizes & sends node ESN
304
Send parameters
wattage, type, etc.
306
Reg. data to be sent
at specific intervalsor when requested
308
Data packet
resend till ack. recd.
310
Acknowledgement

FIG. 3

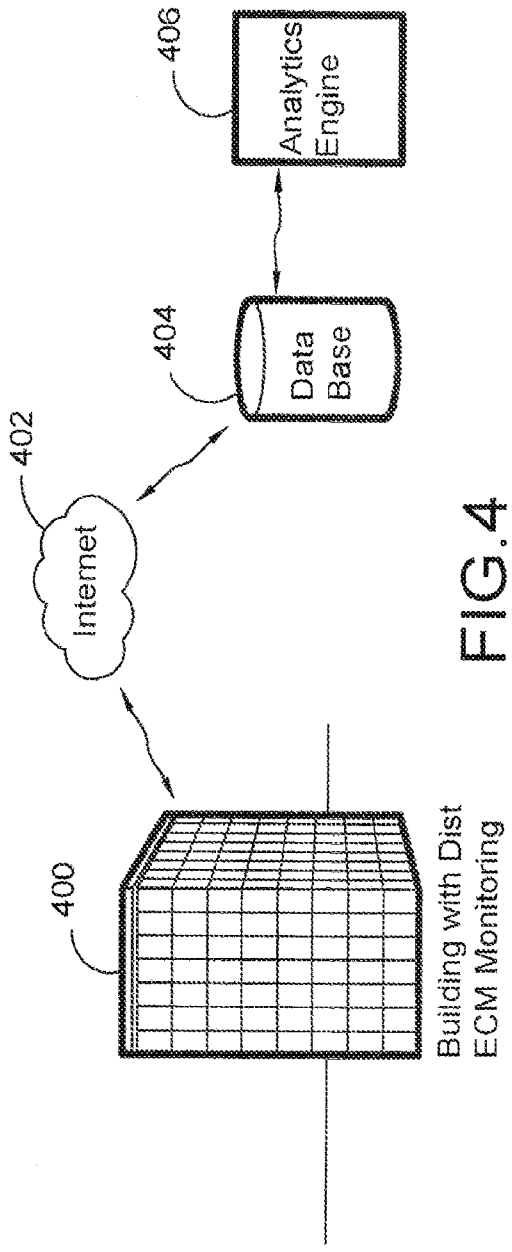
406
Analytics Engine
404
Data Base
402
Internet
400
Building with Dist ECM Monitoring

FIG. 4

Output of Analytics Engine includes:

Energy savings across the globe & carbon footprint

World map showing energy savings due to deployment of ECM by city.

FIG.5

Operations & Maintenance Alets:
- Device Failure alerts
- Device Malfunction alerts
- Device end-of-life alerts

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/0349 4 1

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H02J 3/12 (2013.01)
USPC - 700/291
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - G05D 3/12; G06F 15/16, 15/173; H02J 3/12, 3/14 (2013.01)
USPC - 315/297, 315, 317; 700/291; 709/217, 225

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC: H02J 3/14; H04L 29/06, 29/08072; G05D 3/12 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Advanced Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0301769 A1 (CHEMEL et al) 02 December 2010 (02.12.2010), see entire document.	1-8, 10-14
Y		9, 15
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