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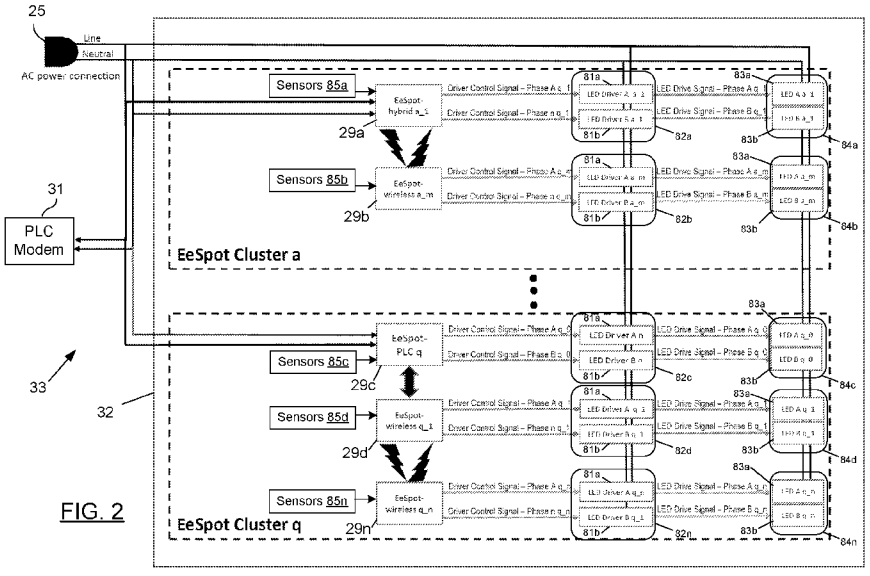

FIG. 2

(57) Abstract: A method for the monitoring and control of remote lighting installations where each installation includes a plurality of luminaire control devices each controlling one or more light sources, including the steps of: placing a central computer in data communication with each of the data luminaire control devices; and operating the central computer to monitor and control each of the plurality of luminaire control devices; wherein the step of placing the central computer in data communication with each of the data luminaire control devices includes establishing data communications with at least one of said control devices across an alternating current (AC) power network that powers said control devices.

[Continued on next page]

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IMPROVEMENTS TO MONITORING AND CONTROL OF REMOTE LIGHTING SITES

TECHNICAL FIELD

The present invention concerns methods and apparatus for monitoring and controlling lighting installations in one or more remote sites. Particular embodiments of the invention provide for sensing and monitoring daylight harvesting, the movement of people, vehicles and equipment, heat, fire and sound from each light source of the lighting installations.

BACKGROUND ART

Any references to methods, apparatus or documents of the prior art are not to be taken as constituting any evidence or admission that they formed, or form part of the common general knowledge.

Providing and managing lighting throughout large sites such as hospitals, airports and shopping centers incurs a substantial initial capital outlay, ongoing maintenance costs for replacement of components such as lamps and electricity costs.

Often the management of lighting installations requires personnel to visit the sites and make visual inspections to confirm correct working of the various lamps. Furthermore, in order to control the configuration of the lighting that is provided at specific sites it may be necessary for personnel to manually adjust settings such as dimmer switches and the like.

It would be desirable if it were possible to reduce the number of onsite inspections that are required to check the status of lighting installations. It would also be desirable if it were possible to remotely control and manage lighting installations.

It is an object of the present invention to provide a method and apparatus for remotely monitoring and controlling a number of lighting installations.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a method for the monitoring and control of remote lighting installations where each installation includes a plurality of luminaire control devices ("EeSpots") each controlling one or more light sources, including the steps of:

placing a central computer in data communication with each of the data luminaire control devices; and

operating the central computer to monitor and control each of the plurality of luminaire control devices;

wherein the step of placing the central computer in data communication with each of the data luminaire control devices includes establishing data communications across an alternating current (AC) power network that powers said control devices.

Preferably, upon the central computer detecting a fault, operating said computer to disable a luminaire control device associated with the fault.

It is preferred that the plurality of luminaire control devices are grouped into clusters wherein at least one luminaire control device in each cluster is a hub device that is equipped with a power line communication (PLC) arrangement to establish data communications across the AC power network to the central computer and wherein the remaining luminaire control devices in each cluster communicate with the hub device of their cluster.

Preferably each hub luminaire control device includes a powerline transceiver wherein the method includes operating a powerline modem of the installation to interface data communications from the central computer to the hub luminaire control devices and thence to remaining luminaire control devices of the installation.

Each luminaire control device may be one of a wireless-only device; a PLC only device or a hybrid device having both wireless communication and PLC capability.

In a preferred embodiment of the invention each luminaire control device controls a pair of light sources wherein one light source is of a different color temperature than the other light source, the method including the steps of operating the central computer to cause the luminaire control devices to vary the intensities of the light sources to produce a desired combination of intensities of the two light sources. Accordingly, the luminaire is able to provide a variation of colour temperatures between the two original light source colour temperatures.

It is preferred that at least one sensor be coupled to each luminaire control device, for example, in one embodiment of the invention the sensor may comprise a light level sensor, wherein the method includes monitoring data from the sensor with the central computer and commanding the luminaire control device to vary the operation of the light sources based on the data from the sensor.

The sensor may include one or more of a motion sensor, heat sensor, fire sensor and sound sensor.

The method preferably includes operating the central computer to transmit configuration data, such as a configuration script, to each luminaire control device.

Preferably the method includes operating the central computer to produce displays relating to the status and control of the luminaire control devices for a human user. For example the displays may indicate the locations on a building plan of the luminaire control devices of a particular installation of interest to the user. Preferably the displays visually indicate the status of each luminaire control device, preferably indicating the operational status of light sources under the control of the luminaire control device.

The displays may also include graphs illustrating parameters such as the operating times of the light sources, power consumptions, sensor activity and alarm states.

According to a further aspect of the present invention there is provided a lighting system including:

a lighting installation having a plurality of luminaire control devices each controlling one or more light sources

a central computer in data communication with each of the data luminaire control devices and programmed to monitor and control each of the plurality of luminaire control devices;

at least one power line communication (PLC) data network device coupled to the central computer and providing data communication across an alternating current (AC) power network that powers said control devices to establish the data communication between each of the data luminaire control devices and the central computer.

The plurality of luminaire control devices may be grouped into clusters wherein at least one luminaire control device in each cluster is a hub device that is equipped with a power line communication (PLC) arrangement to communicate with the PLC data network network.

Each hub luminaire control device preferably includes a powerline transceiver to interface data communications from the central computer to the hub luminaire control devices via said transceiver and thence to remaining luminaire control devices of the installation.

The luminaire control devices are preferably selected from: a wireless-only device; a PLC only device; or a hybrid device having both wireless communication and PLC capability.

The system may include pairs of light sources of different color temperatures with each said pair being responsive to a corresponding luminaire control device wherein the central computer is programmed to cause the luminaire control devices to vary the intensities of the light sources to produce a desired combination of intensities of the two light sources to thereby provide a variation of color temperatures between the two original light source color temperatures.

At least one sensor is preferably coupled to each luminaire control device.

According to a further aspect of the present invention there is provided a luminaire control device including:

a programmable controller;

a powerline data port coupled to the programmable controller for data communications across an alternating current (AC) power network;

an LED driver control interface coupled to the programmable controller for controlling LEDs in response to signals from the programmable controller; and

a sensor interface for receiving signals from a sensor for monitoring one or more parameters of the local environment.

The luminaire control device may further include a wireless transceiver for data communication with other similar luminaire control devices.

In a preferred embodiment of the invention the LED driver control interface is arranged to independently control two LEDs.

The computer server luminaire control device may be provided in combination with LED drivers and LEDs, wherein the LEDs are of different color temperatures for producing an overall combined light of a desired color temperature in response to independent control signals from the LED driver control interface.

Preferably the programmable controller operates according to a configuration script received across a data network from a central controller.

Preferably the programmable controller is programmed to transmit data from the sensor interface via the powerline data port to a remote central computer across the AC power network.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows:

Figure 1 is a block diagram of a system for monitoring and controlling a plurality of lighting sites according to a preferred embodiment of the present invention.

Figure 2 is a block diagram of a lighting control and monitoring assembly ("EeSpot Assembly) of Figure 1.

Figure 3 is a block diagram of a hybrid power line communications (PLC) and wireless luminaire control device ("EeSpot-Hybrid") according to a preferred embodiment of the present invention.

Figure 4 is a block diagram of a PLC luminaire control device ("EeSpot-PLC") according to a preferred embodiment of the present invention.

Figure 5 is a block diagram of a wireless luminaire control device ("EeSpot-Wireless") according to a preferred embodiment of the present invention.

Figure 6 depicts the exteriors of various components of an EeSpot-PLC Assembly of Figure 1.

Figure 7 is a block diagram of a luminaire control device ("EeSpot-PLC") wired to control two LED lamps of differing colour temperature.

Figure 8 is a graph showing how changing the dimming levels of the two lamps of Figure 7 results in a combined output from the lamps of differing colour temperatures.

Figure 9 is a block diagram of a central computer in the form of a server that is specially programmed with lighting monitoring and control software according to a preferred embodiment of the present invention.

Figure 10 is a high level flowchart showing steps that are performed by the server of Figure 9 under control of the lighting and control software.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to Figure 1 there is illustrated a monitoring and lighting control system 1 according to a preferred embodiment of the present invention. The system 1 may be implemented as either a retrofit to an existing lighting system or along with a new lighting system installation. As will be explained further shortly, the system 1 involves the user of a Powerline Control/Communication modem (PLC) 31 to allow monitoring and control of factory, retail or other industrial or commercial lighting at each of a number of sites 5a,..,5n. The system 1 provides for functionality such as the collection of customer diagnostics and security functions.

The system 1 comprises a central infrastructure which in the present embodiment is provided as a specially programmed computer server 60. The server 60 is in data communication with the plurality of on-site lighting installations 5a,...,5n by means of a router 47 that is in data communication with the internet 45. A back up mobile broadband link is also provided that is implemented by a USB broadband modem 43 that has an antenna 41 which communicates wirelessly with a node 39a of a cellular telephone network in communication with the internet 45.

Similarly each of the on-site lighting installations 5a,..,5n is able to communicate with the central server 60 by means of a router 37 and mobile broadband USB modem 35. The mobile broadband USB modem 35 communicates with internet 45 via cellular telephone network node 39m.

Each on-site lighting installation 5a,..,5n includes an "EeSpot" assembly 33 that communicates with the data modem 37 by means of power line communication (PLC) modem 31.

Referring now to Figure 2, the EeSpot assembly 33 comprises a number of "EeSpots" 29a,..,29n. In the presently described preferred embodiment there are three types of EeSpots namely Hybrid EeSpots such as EeSpot-Hybrid 29a, wireless only EeSpots, such as EeSpot-Wireless 29b and 29n, and PLC EeSpots such as EeSpot-PLC 29c. As will be explained, EeSpot-Hybrids and EeSpot-PLCs include a microcontroller that is programmed to receive and send data across a mains power supply by means of a powerline transceiver. EeSpot-Hybrids and EeSpot-Wireless units are equipped with wireless transceivers so that they can communicate with each other wirelessly. If required the central computer 60 may send a configuration script 36 to a particular one, or to all, EeSpots to alter their functionality if necessary.

With reference to Figure 2, EeSpot clusters a...q are in general each comprised of either a single EeSpot-hybrid communicating wirelessly with several EeSpot-wireless units, or, a single EeSpot-PLC connected via a communication cable to a single EeSpot-wireless which acts as an RF gateway to all other EeSpot-wireless units in the same cluster. PLC communication occurs between the EeSpot-hybrid and EeSpot-PLC units via the on-site PLC-modem/router to externally located central infrastructure.

The RF link between EeSpots is either a hub-spoke topology with EeSpot-hybrid a_1 acting as a hub for a_2 ... a_m, or alternately there is a mesh topology between all m nodes. In EeSpot cluster q EeSpot-PLC q has a local wired link to EeSpot-wireless q_1 which acts as its RF gateway to EeSpot-wireless q_2 ... q_n. In EeSpot Cluster q, the RF link between EeSpots is either a hub-spoke topology with EeSpot-wireless q_1 acting as a hub for q_2 ... q_n, alternately there is a mesh topology between all n nodes.

Each EeSpot 29a-29n is able to receive data from a respective sensor 85a-85n and to produce driver control signals for driving LED Drivers 82a,..,82n that in turn produces LED drive signals for activating LEDs 83a and 83b of luminaires 84a-84n.

Figure 3 comprises a block diagram of an exemplary EeSpot-Hybrid unit 29a. The EeSpot-Hybrid 29a sources its power directly from the same AC mains power connection 25 that it uses to communicate with server 60 via PLC Modem 31. It includes on offline AC-DC switch mode converter 71 to generate low-voltage DC power for internal circuits. It contains a microcontroller 73, which includes a CPU 70 and which may or may not be combined with a System-on-Chip (SoC), to implement an Inter-EeSpot wireless protocol stack 75a, a PLC communication Protocol Stack 74 and memory for storage of configuration data. Microcontroller 74 controls lighting LED/LEDs via LED driver control interface 77 and performs health status monitoring routines in respect of itself and the driver and LED.

Figure 4 comprises a block diagram of an exemplary EeSpot-PLC unit 29c. The EeSpot-Hybrid 29a sources its power directly from the same AC mains power connection 25 that it uses to communicate with server 60 via PLC Modem 31. It includes on offline AC-DC switch mode converter 71 to generate low-voltage DC power for internal circuits. It contains a microcontroller 73, which includes a CPU 70 and which may or may not be combined with a System-on-Chip (SoC), to implement an Inter-EeSpot wired protocol stack 75c, a PLC communication Protocol Stack 74 and memory for storage of configuration data. Microcontroller 74 controls lighting LED/LEDs via LED driver control interface 77 and performs health status monitoring routines in respect of itself and the driver and LED. EeSpot-PLC 29c can communicate with Inter-EeSpot Wired signal interfaces 91 of other EeSpots via an Inter-Espot signal bus 76.

Figure 5 comprises a block diagram of an exemplary EeSpot-Wireless unit 29d. The EeSpot-Wireless unit 29d sources its power from mains power connection 25. However the EeSpot-Wireless unit does not include the

Powerline Transceiver 62 and AC line coupler 64 of the Hybrid and PLC EeSpots and so it cannot communicate with server 60 via PLC Modem 31. Instead EeSpot-Wireless unit 29d communicates either via a wired inter-EeSpot signal bus 76 or wirelessly via transceiver 78 with other EeSpots, including EeSpot-Hybrid and EeSpot-PLC modules that are able to communicate with the server 60 and thus forward data to the server.

The EeSpot-Wireless unit 29d includes includes an offline AC-DC switch mode converter 71 to generate low-voltage DC power for internal circuits. It contains a microcontroller 73, which includes a CPU 70 and which may or may not be combined with a System-on-Chip (SoC), to implement an Inter-EeSpot wireless protocol stack 75a, and an Inter-EeSpot wired Protocol Stack 75c and memory for storage of configuration data. Microcontroller 73 controls lighting LED/LEDs via LED driver control interface 77 and performs health status monitoring routines in respect of itself and the driver and LED.

In practice most of the EeSpots that are used in the EeSpot Assembly 33 are EeSpot-Wireless Units. The advantages of the EeSpot-Wireless units 29d are that the are physically lighter, more compact and less expensive than the EeSpot-Hybrid and EeSpot-PLC units since they do not include powerline transceiver 62 or AC line coupler 64.

Each of EeSpot 29 is primarily for control of the individual LED luminaire 84a via associated driver unit 82a. Each EeSpot 29 can accept analog or digital inputs from light, motion, or other sensors 85 via sensor interface 79, that enhance functionality for value added services.

Figure 6 is a physical representation that shows the external appearance of an EeSpot-PLC 29c, LED driver 81, sensor 85 and luminaire 83, which houses a pair of differently colored, and independently controllable LEDs 83a, 83b.

For setting luminaire intensity, the LED driver interface 77 has both a standard analog 0-10V level based interface as well as a Pulse-Width-Modulation (PWM) based interface. Each interface has two independent channels so that

an EeSpot can optionally implement the mood lighting value added feature. For example Figure 7 shows an EeSpot driving two lamps via Output1 and Output 2 wherein the two lamps are respectively loaded with a 2700K color temperature LED (yellowish) and a 5000K colour temperature LED (bluish). By varying the dimming levels that the EeSpot applies to Lamp 1 and Lamp 2 a range of overall colour temperatures may be produced by the pair of lamps as indicated in the graph of Figure 8.

Referring now to Figure 9, there is illustrated a block diagram of the server 60.

The server 60 includes a main board 34 which includes circuitry for powering and interfacing to at least one onboard central processing unit or "processor" or "microprocessor" 35. The at least one onboard processor 35 may comprise two or more discrete processors or processors with multiple processing cores.

The main board 34 acts as an interface between CPUs 35 and secondary memory 44. The secondary memory 44 which is typically implemented by a magnetic or solid state data drive and which stores a server operating system, for example *Microsoft Windows Server*, *Linux Ubuntu Server* are two examples of such an operating system. The main board 34 also communicates with random access memory 41 and read only memory 43. The ROM 43 typically stores instructions for a Basic Input Output System (BIOS) which the CPUs 35 access upon start up and which prepares the CPUs 35 for loading of the operating system 39 from secondary memory 44.

The main board 34 will typically include a communications adapter, for example a LAN adaptor 53 that places the server 60 in data communication with a computer network such as the Internet 45 via router 47 or other suitable network interface device.

The server 60 may include a human-to-machine interface (HMI) in the form of keyboard 49, mouse 21 and display 48 which enables an operator 116 to directly enter commands, read output, and generally interact with the server as the CPUs 35 execute various operating system and application software

instructions. Alternatively, and more commonly, the operator 116 logs into the server 60 remotely over the Internet 45 or another data network and interacts with server 60 remotely using a local terminal as the HMI. For example, with reference to Figure 1, a mobile EeOSS console may be provided in the form of a suitably programmed computational device 61 such as a tablet computer, smartphone or other portable device that is capable of establishing data communications with the server 60.

Referring again to Figure 9, the secondary storage 44 also stores a remote lighting installation monitoring and control software product 80 according to a preferred embodiment of the present invention, which is referred to herein as "EeOSS" 80. During operation of the server 60 the server processor assembly 35 loads the operating system 39 and then loads the EeOSS software product 80.

EeOSS

The EeOSS 80 is an EcoEnergy Operation Support System software product which is centrally located on server 60 but which may be accessed remotely over the internet. The EeOSS 60 embodies the monitoring and control functionality for any number of the lighting installation sites 5a,..,5n and for the individual components within sites. The EeOSS software product 80 is comprised of a number of elements as follows:

- EeMonitor 82
- EeController 84
- EeConfigure 86
- EeDatabase 88
- EeOss Console 90

EeMonitor

The EeMonitor software component 82 allows the real-time visibility and recording of site and individual EeSpot parameters for, including but not limited to:

- A dashboard, e.g. as shown on display 48 of Figure 9 with hierarchical based interaction as follows:
  - Geographic Information System (GIS) view of sites, with clickable icons for accessing individual site status and data,
  - Graphical and tabular summary of monitored sites, showing alarms and general status, recorded time-series of measured parameters, e.g. graphs, and
  - a floorplan or schematic based view for each site.

- Supplementary graphical and tabular summaries for visualisation of EeSpot and luminaire status and history showing:
  - the quantity and list of EeSpots per site,
  - the quantity of each type of EeSpot (i.e. Wireless, PLC only, or Hybrid)
  - the individual EeSpot status for any site,
  - summary of EeSpot measurements and trends per site,
  - if the number of operational EeSpots on a site changes,
  - if the feature and applicable sensors are installed, people diagnostics
    - a tally and trend of passing people per EeSpot or visiting people per site, and
    - the average visit time and trend per site,
  - alarm functions for exception conditions
    - unusual EeSpot power consumption,
    - high EeSpot temperature,
    - broken communication paths within or to EeSpot arrays.
    - luminaire failures,
    - sensor failures,
    - that a person has entered a prohibited area, and
    - clear or acknowledge alarms

- export of recorded data into generic file types suitable for spreadsheet or other file import.

Each

EeConfigure

The EeConfigure software component 86 of EeOSS 80 is for configuring the lighting and measurement profile of each site. It is based upon preparing default templates for the site EeSpots but still allows customisation down to the level of an individual EeSpot. In accordance with Figure 3 it is executed at the time a site is first commissioned or whenever EeSpots are to be added or removed. It is for configuration of:

- default site EeSpot/LED settings,
- individual EeSpot/LED settings,
- commissioning more EeSpots on a site in general,
- associating wireless EeSpots in a "spoke" node with those in a "hub" node,
- commissioning an entire site,
- decommissioning an entire site,
- decommissioning individual EeSpots on a site,
- site light intensity profile for day, week, month or season,
- EeSpot measurement and status data upload time and or frequency,
- light colour temperature,
- daylight harvesting thresholds,
- alarming thresholds,
- customer diagnostic parameters, and
- security feature thresholds.

EeController

The EeController software component 84 of EeOSS 80 transmits the configuration to each EeSpot 29a,..,29n and periodically polls each EeSpot 29a,..29n for measurement and status data. The EeController software

component 84 communicates over the internet 45 with the remote sites 5a,.., 5n. At each site, e.g. site 5a, its router 37 mediates the communication to/from EeSpots 29a,..,29n of the EeSpot assembly 33 via a PLC modem 31 which translates the transmission protocol from router 37 to a PLC one carried over the local AC main wiring infrastructure of the site. This PLC protocol can be any one including but not limited to *LonWorks*, *G3*, *Prime* etc. Software in the PLC modem 31 or an associated platform will do any link or transport layer conversion required such as mapping TCP/IP MAC addresses to a non TCP/IP one so that the EeSpots 29a,...,29n can be individually addressed.

The EeController communicates with each wireless EeSpot unit via an intermediate PLC capable EeSpot (e.g. EeSpot-Hybrid unit 29a and EeSpot-PLC unit 29c of Figure 2) which acts as a "Hub EeSpot". A Hub EeSpot will mediate the communication in a transparent manner and for the purposes of network communication wireless EeSpot units appear to the EeController to be directly connected.

EeOSS Console

The EeOSS Console 90 generates a system adminstrator control display on screen 48 (or on a screen of the mobile device 61) that provides an override capability for the administrator to directly enable or disable individual EeSpot units 29a,..,29n and their associated luminaires for the purpose of testing and fault identification including the following functionalities:

- turn individual or all of site luminaires ON or OFF,
- turn individual EeSpot or all of site EeSpots ON or OFF,
- turn site monitoring features ON or OFF,
- turn site value added features ON or OFF,
- download configuration data to site EeSpots, and
- upload measurement and status data from site EeSpots.

EeOSS Database

EeOSS 80 implements and maintains the EeSystem database 92 that is also stored in the secondary storage 44. Data associated with the operation of the EeSpots 29 for each site 5a,...,5n is stored in the database 92 so that reports and logs may be subsequently viewed by the operator.

It will be realised that the exemplary computer server 60 that is illustrated in Figure 9 comprises a discrete hardware machine that is suitably programmed. In other embodiments of the invention the server may be implemented by a virtual machine, e.g. a "cloud server" that uses shared hardware resources of a "server farm" as required.

Figure 10 is a high level flowchart of the steps that are performed by EeOSS 80 running on server 60. These steps are comprised of "configuration states" 100, operational states 101 and remedial states 103.

The configuration states 101 involve registering all current EeSpots, checking that each EeSpot 29 is configured according to a pre-stored configuration script and if there is a mis-match rectifying either the script or correcting an EeSpot physical connection. Configuration scripts are then loaded into new EeSpots. The possible EeSpot states are:

- not_commissioned_and_not_configured
- commissioned_and not_configured
- commissioned_and_configured

The operational states 103 involve monitoring each EeSpot to detect a status change or a fault condition. Various parameters may be monitored including:

- EeSpot Measurements
- input AC Voltage
- input AC Current
- input Power Factor
- Power Consumption - EeSpot

- temperature - EeSpot
- Power Consumption - LED and Driver
- LED status as either GOOD, MARGINAL, or BAD
- Environment Measurements (per EeSpot fitted with sensor)
- light intensity - ambient to EeSpot from local sensor
- motion - local to EeSpot

The EeMonitor is able to provide information to a user including:
quantity and list of EeSpots per site
individual EeSpot status for any site
summary of EeSpot power and energy measurements and trends per site
alarm condition alerts
people diagnostics
- tally and trend of passing people (vehicles or machinery) per EeSpot or visting people per site
- average visit time and trend per site
alarm functions
- unusual EeSpot power consumption
- number of EeSpots on a site changes
- high EeSpot temperature
- luminaire failure detected
- sensor failure
- person has entered a prohibited area

operational configuration
- site light intensity profile for day, week, month or season
- set compound LED colour temperature
- daylight harvesting thresholds
- alarming thresholds
- default site EeSpot/LED settings
- individual EeSpot/LED settings
- commission more EeSpots on a site
- commission a site

- decommission a site
- decommission EeSpots on a site

During the operational states 103 the following functions may also be implemented:
- turn individual or all of site luminaires ON or OFF
- turn site monitoring features ON or OFF
- clear or acknowledge alarms

If a fault condition is detected during the operational states 103 then the remedial states 105 are entered in which alarms are activated and fault affected EeSpots are disabled.

Enhanced functionality supported via each EeSpot 29 includes:

Mood Lighting

This function uses the two independent intensity channels that can control separately the intensity of each of two LEDs as a pair that are either an integrated unit or closely spaced individual units, e.g. LEDs 83a and 83b of luminaire 83 (Figure 2). By changing the relative intensity of the two LEDs (which have distinctly different colour temperatures) the resulting mixing action produces a desirable colour.

Daylight Harvesting

For site LEDs that are in locations exposed to daylight of significant intensity, digital processing of the light sensor input 85 can be used by server 60 to determine a reduced intensity setting that takes into account the light already present. This setting is then transmitted to the luminaire control device 29, to reduce electricity usage by the LEDs.

People Diagnostics

Where the sensors 85 include a motion sensor then data from the motion sensor can be used to collect data about the number and frequency of people, (vehicles or machinery) passing within the vicinity of the EeSpot. This

information could be used to assist a site operator (e.g. a retail store) to collect statistics about the most popular places and visited areas.

Security Alerts

The motion sensor input can be used to determine somebody entering a prohibited or sensitive area.

A smoke or gas sensor may also be used to detect a dangerous condition and as such the EeMonitor can be used as a source trigger for emergency action.

In use the EeOss running on server 60 initiates communications with any EeSpot in any one of the EeSpot assemblies 33 of the various sites 5a,..,5n. Simmilarly any EeSpot can initiate communication with the EeOSS either directly or indirectly. Similarly, an operator may use a mobile EeOSS console, e.g. item 61 of Figure 1 and communication between the mobile EeOSS console and any of the EeSpots can be established. Further more, any EeSpot can initiate communication with any other EeSpot at the same site via a local on-site router.

Each site 5a,..,5n is notionally organised as one array 32 (Fig 2) of EeSpots, LED drivers and Luminaires containing LEDs. The array is segmented into one or more clusters, e.g. Clusters a…q of Figure 2 with each cluster having a single PLC capable EeSpot such as EeSpot-PLC 29c or EeSpot-Hybrid 29a. The PLC capable unit of each cluster mediates communication between its cluster and the EeOSS via the PLC modem 31 so that the remaining EeSpots in each cluster can be ligher and cheaper EeSpot-Wireless units e.g. EeSpots 29B, 29d, 29n.

As previously stated, no specific PowerLine Communication standard is implied and the PLC capable EeSpot units may use *LonWorks*, *Prime*, *G3* or some other protocol.

Similarly no specific wireless standard is implied for wireless only and hybrid EeSpots and any RF or optical method including but not limited to the following may be used:

- Bluetooth and its variants,
- 802.11 WiFi and its variants,
- 802.15.4
- Most proprietary RF data communication methods.

In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. The term “comprises” and its variations, such as “comprising” and “comprised of” is used throughout in an inclusive sense and not to the exclusion of any additional features. It is to be understood that the invention is not limited to specific features shown or described since the means herein described herein comprises preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted by those skilled in the art.

Throughout the specification and claims (if present), unless the context requires otherwise, the term "substantially" or "about" will be understood to not be limited to the value for the range qualified by the terms.

Any embodiment of the invention is meant to be illustrative only and is not meant to be limiting to the invention. Therefore, it should be appreciated that various other changes and modifications can be made to any embodiment described without departing from the spirit and scope of the invention.

CLAIMS:

1. A method for the monitoring and control of remote lighting installations where each installation includes a plurality of luminaire control devices each controlling one or more light sources, including the steps of:

placing a central computer in data communication with each of the data luminaire control devices; and

operating the central computer to monitor and control each of the plurality of luminaire control devices;

wherein the step of placing the central computer in data communication with each of the data luminaire control devices includes establishing data communications with at least one of said control devices across an alternating current (AC) power network that powers said control devices.

2. A method according to claim 1, wherein the plurality of luminaire control devices are grouped into clusters wherein at least one luminaire control device in each cluster is a hub device that is equipped with a power line communication (PLC) arrangement to establish data communications across the AC power network to the central computer and wherein the remaining luminaire control devices in each cluster communicate with the hub device of their cluster.

3. A method according to claim 2, wherein each hub luminaire control device includes a powerline transceiver wherein the method includes operating a powerline modem of the installation to interface data communications from the central computer to the hub luminaire control devices via said transceiver and thence to remaining luminaire control devices of the installation.

4. A method according to any one of the preceding claims wherein the luminaire control devices are selected from: a wireless-only device; a PLC only device; or a hybrid device having both wireless communication and PLC capability.

5. A method according to any one of the preceding claims, wherein each luminaire control device controls a pair of light sources wherein one light source is of a different color temperature than the other light source, the method including:

operating the central computer to cause the luminaire control devices to vary the intensities of the light sources to produce a desired combination of intensities of the two light sources to thereby provide a variation of color temperatures between the two original light source color temperatures.

6. A method according to any one of the preceding claims including at least one sensor coupled to each luminaire control device.

7. A method according to claim 6, wherein said sensor comprises a light level sensor, wherein the method includes monitoring data from the sensor with the central computer and commanding the luminaire control device to vary the operation of the light sources based on the data from the sensor.

8. A method according to claim 6, wherein the sensor comprises one or more of a motion sensor, heat sensor, fire sensor and sound sensor.

9. A method according to any one of the preceding claims, including operating the central computer to transmit a configuration script, to each luminaire control device.

10. A method according to any one of the preceding claims, including operating the central computer to produce displays relating to the status and control of the luminaire control devices for a human user.

11. A method according to any one of the preceding claims wherein the displays visually indicate the status of each luminaire control device.

12. A method according to claim 10 or claim 12, including operating the central computer to produce displays including graphs illustrating operational parameters of the light sources.

13. A method according to any one of the preceding claims, wherein upon the central computer detecting a fault, operating said computer to disable a luminaire control device associated with the fault.

14. A lighting system including:

a lighting installation having a plurality of luminaire control devices each controlling one or more light sources

a central computer in data communication with each of the data luminaire control devices and programmed to monitor and control each of the plurality of luminaire control devices;

at least one power line communication (PLC) data network device coupled to the central computer and providing data communication across an alternating current (AC) power network that powers said control devices to establish the data communication between each of the data luminaire control devices and the central computer.

15. A lighting system according to claim 14, wherein the plurality of luminaire control devices are grouped into clusters wherein at least one luminaire control device in each cluster is a hub device that is equipped with a power line communication (PLC) arrangement to communicate with the PLC data network network.

16. A lighting system according to claim 15, wherein each hub luminaire control device includes a powerline transceiver to interface data communications from the central computer to the hub luminaire control devices via said transceiver and thence to remaining luminaire control devices of the installation.

17. A lighting system according to claim 16, wherein the luminaire control devices are selected from: a wireless-only device; a PLC only device; or a hybrid device having both wireless communication and PLC capability.

18. A lighting system according to any one of claims 14 to 17, including pairs of light sources of different color temperatures with each said pair being responsive to a corresponding luminaire control device wherein the central computer is programmed to cause the luminaire control devices to vary the intensities of the light sources to produce a desired combination of intensities of the two light sources to thereby provide a variation of color temperatures between the two original light source color temperatures.

19. A lighting system according to any one of claims 14 to 18, including at least one sensor coupled to each luminaire control device.

20. A luminaire control device including:

a programmable controller;

a powerline data port coupled to the programmable controller for data communications across an alternating current (AC) power network;

an LED driver control interface coupled to the programmable controller for controlling LEDs in response to signals from the programmable controller; and

a sensor interface for receiving signals from a sensor for monitoring one or more parameters of the local environment.

21. A luminaire control device according to claim 20 including a wireless transceiver for data communication with other similar luminaire control devices.

22. A luminaire control device according to claim 21, wherein the LED driver control interface is arranged to independently control two LEDs.

23. A luminaire control device according to claim 22 in combination with LED drivers and LEDs, wherein the LEDs are of different color temperatures for producing an overall combined light of a desired color temperature in response to independent control signals from the LED driver control interface.

* * *

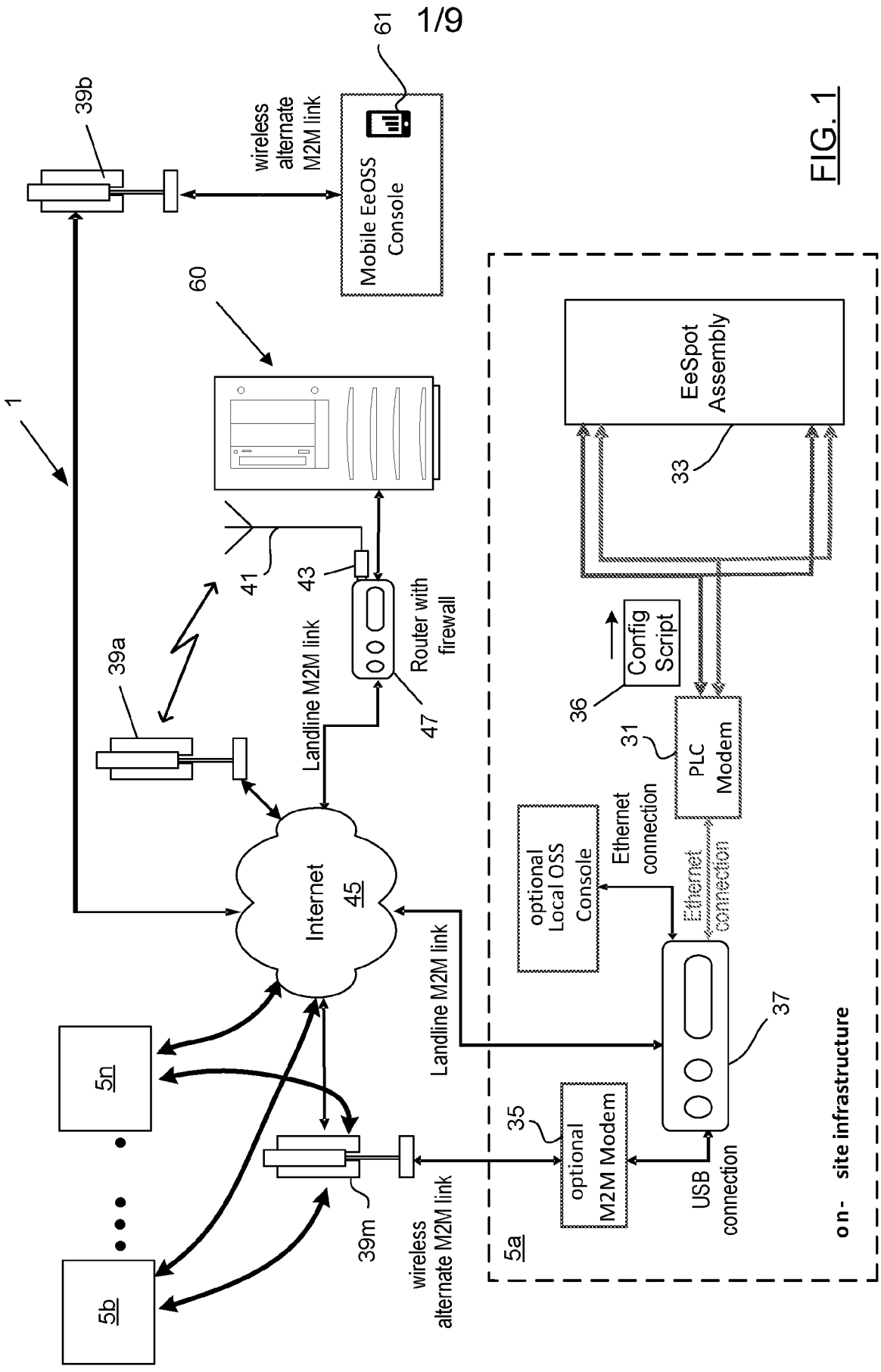
1
39b
wireless alternate M2M link
61
Mobile EeOSS Console
60
41
43
Router with firewall
47
39a
Landline M2M link
Internet 45
5n
5b
39m
wireless alternate M2M link
Landline M2M link
5a
35
optional M2M Modem
USB connection
37
optional Local OSS Console
Ethernet connection
Ethernet connection
31
PLC Modem
36
Config Script
EeSpot Assembly
33
on- site infrastructure

FIG. 1

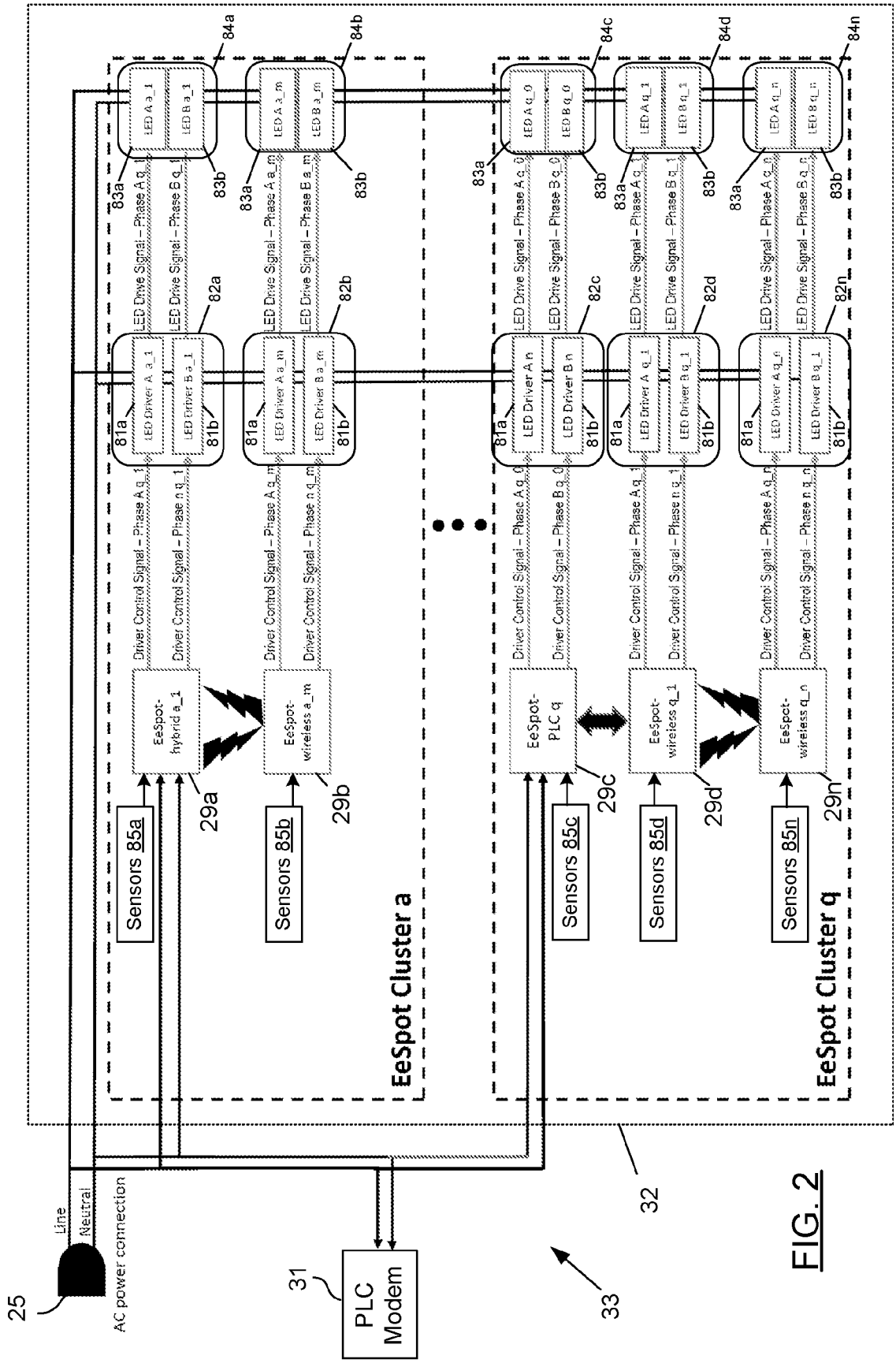
EeSpot Cluster a
EeSpot Cluster q
Sensors 85a
Sensors 85b
Sensors 85c
Sensors 85d
Sensors 85n
EeSpot-hybrid a_1
EeSpot-wireless a_m
EeSpot-PLC q
EeSpot-wireless q_1
EeSpot-wireless q_n
29a
29b
29c
29d
29n
81a
81b
82a
82b
82c
82d
82n
83a
83b
84a
84b
84c
84d
84n
Driver Control Signal – Phase A a_1
Driver Control Signal – Phase n a_1
Driver Control Signal – Phase A a_m
Driver Control Signal – Phase n a_m
Driver Control Signal – Phase A q_0
Driver Control Signal – Phase B q_0
Driver Control Signal – Phase A q_1
Driver Control Signal – Phase n q_1
Driver Control Signal – Phase A q_n
Driver Control Signal – Phase n q_n
LED Drive Signal – Phase A a_1
LED Drive Signal – Phase B a_1
LED Drive Signal – Phase A a_m
LED Drive Signal – Phase B a_m
LED Drive Signal – Phase A q_0
LED Drive Signal – Phase B q_0
LED Drive Signal – Phase A q_1
LED Drive Signal – Phase B q_1
LED Drive Signal – Phase A q_n
LED Drive Signal – Phase B q_n
LED Driver A a_1
LED Driver B a_1
LED Driver A a_m
LED Driver B a_m
LED Driver A n
LED Driver B n
LED Driver A q_1
LED Driver B q_1
LED Driver A q_n
LED Driver B q_n
LED A a_1
LED B a_1
LED A a_m
LED B a_m
LED A q_0
LED B q_0
LED A q_1
LED B q_1
LED A q_n
LED B q_n
Line
Neutral
AC power connection
25
31
PLC Modem
32
33

FIG. 2

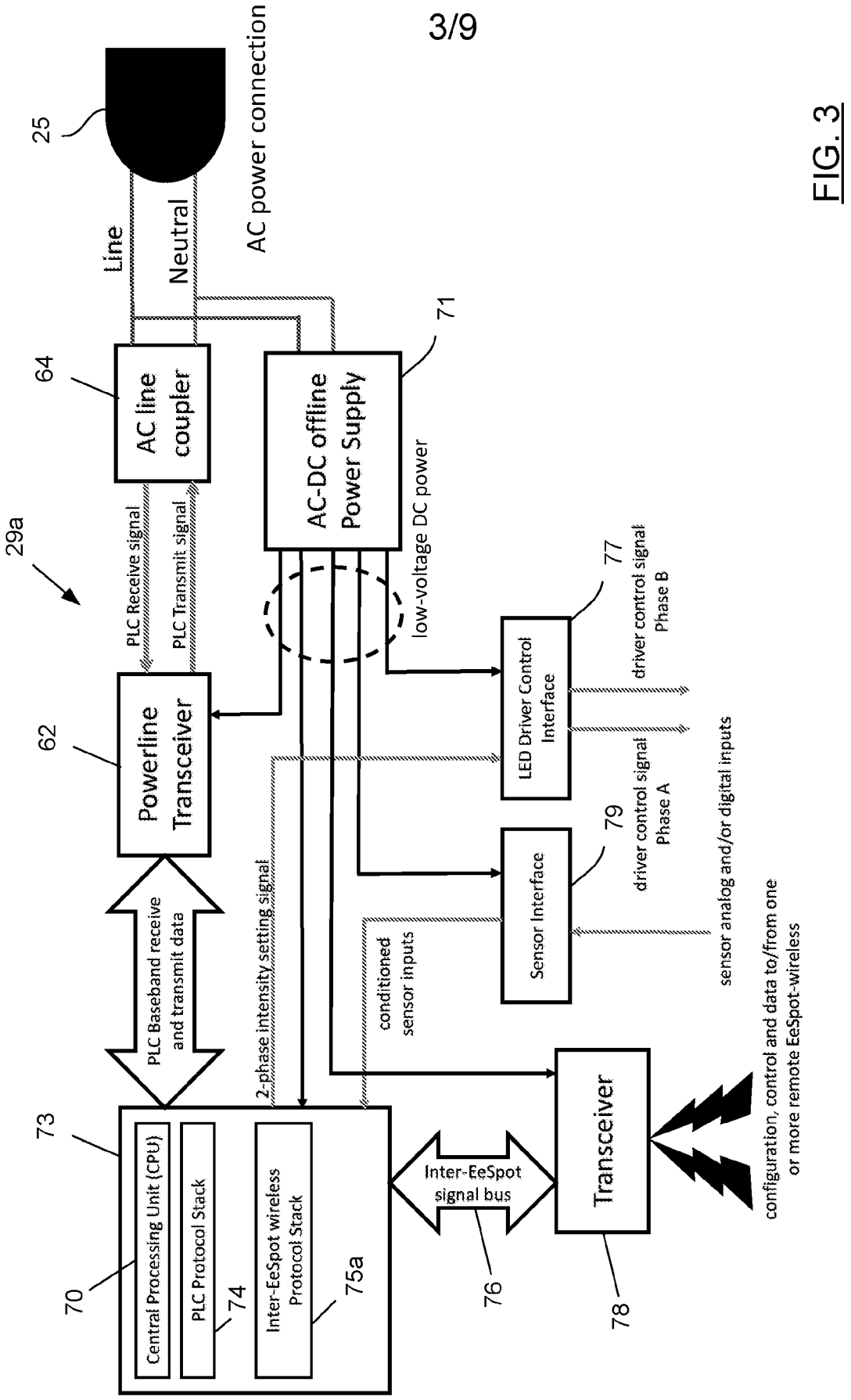
25
AC power connection
Line
Neutral
64
AC line coupler
71
AC-DC offline Power Supply
low-voltage DC power
29a
PLC Receive signal
PLC Transmit signal
62
Powerline Transceiver
PLC Baseband receive and transmit data
2-phase intensity setting signal
77
LED Driver Control Interface
driver control signal Phase B
driver control signal Phase A
79
Sensor Interface
conditioned sensor inputs
sensor analog and/or digital inputs
73
Central Processing Unit (CPU)
PLC Protocol Stack
74
Inter-EeSpot wireless Protocol Stack
75a
70
Inter-EeSpot signal bus
76
Transceiver
78
configuration, control and data to/from one or more remote EeSpot-wireless

FIG. 3

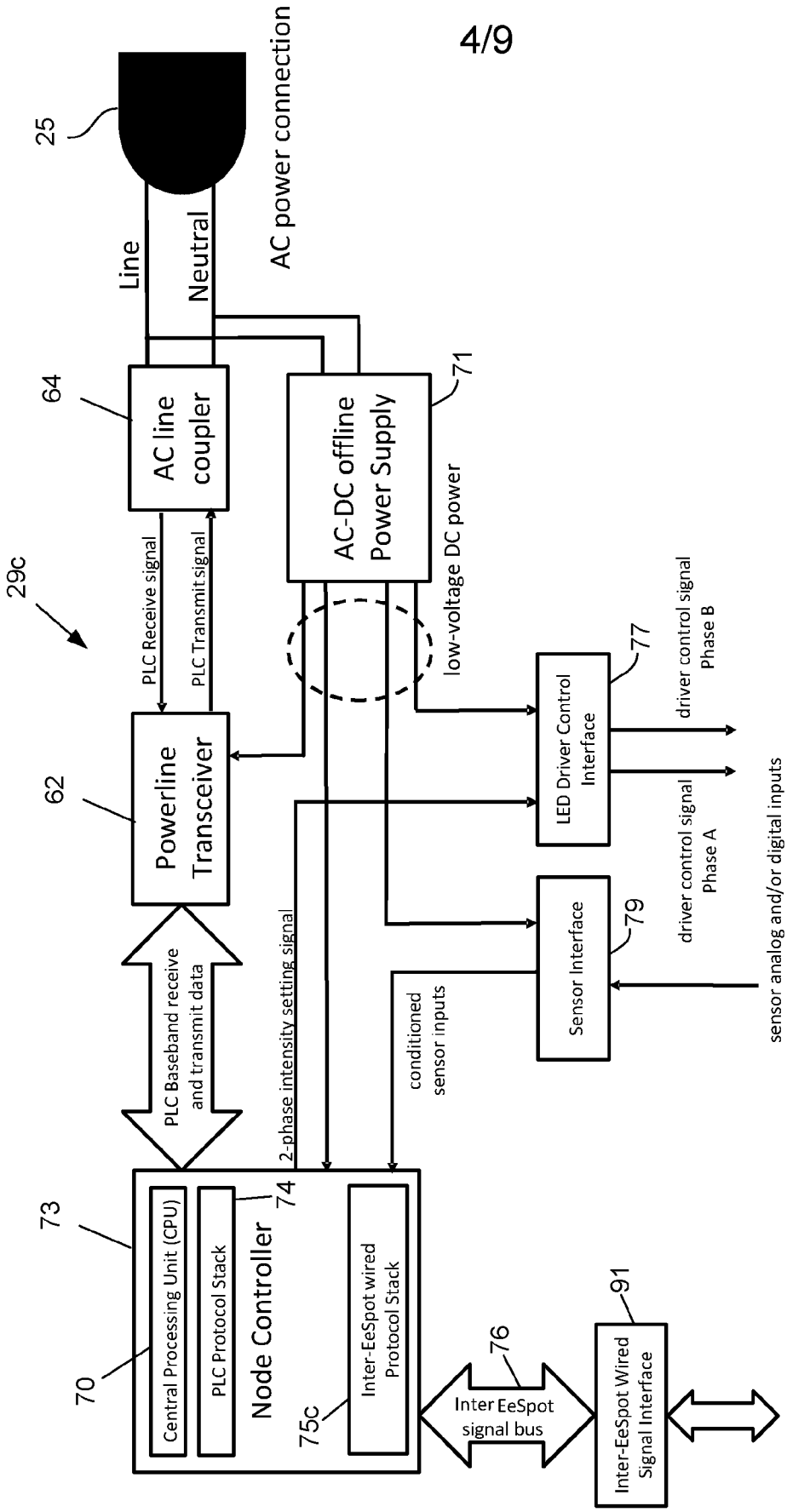
25
AC power connection
Line
Neutral
64
AC line coupler
AC-DC offline Power Supply
71
29c
PLC Receive signal
PLC Transmit signal
low-voltage DC power
77
LED Driver Control Interface
driver control signal Phase B
driver control signal Phase A
62
Powerline Transceiver
PLC Baseband receive and transmit data
2-phase intensity setting signal
conditioned sensor inputs
79
Sensor Interface
sensor analog and/or digital inputs
73
74
Central Processing Unit (CPU)
PLC Protocol Stack
Node Controller
70
75c
Inter-EeSpot wired Protocol Stack
76
Inter EeSpot signal bus
91
Inter-EeSpot Wired Signal Interface

FIG. 4

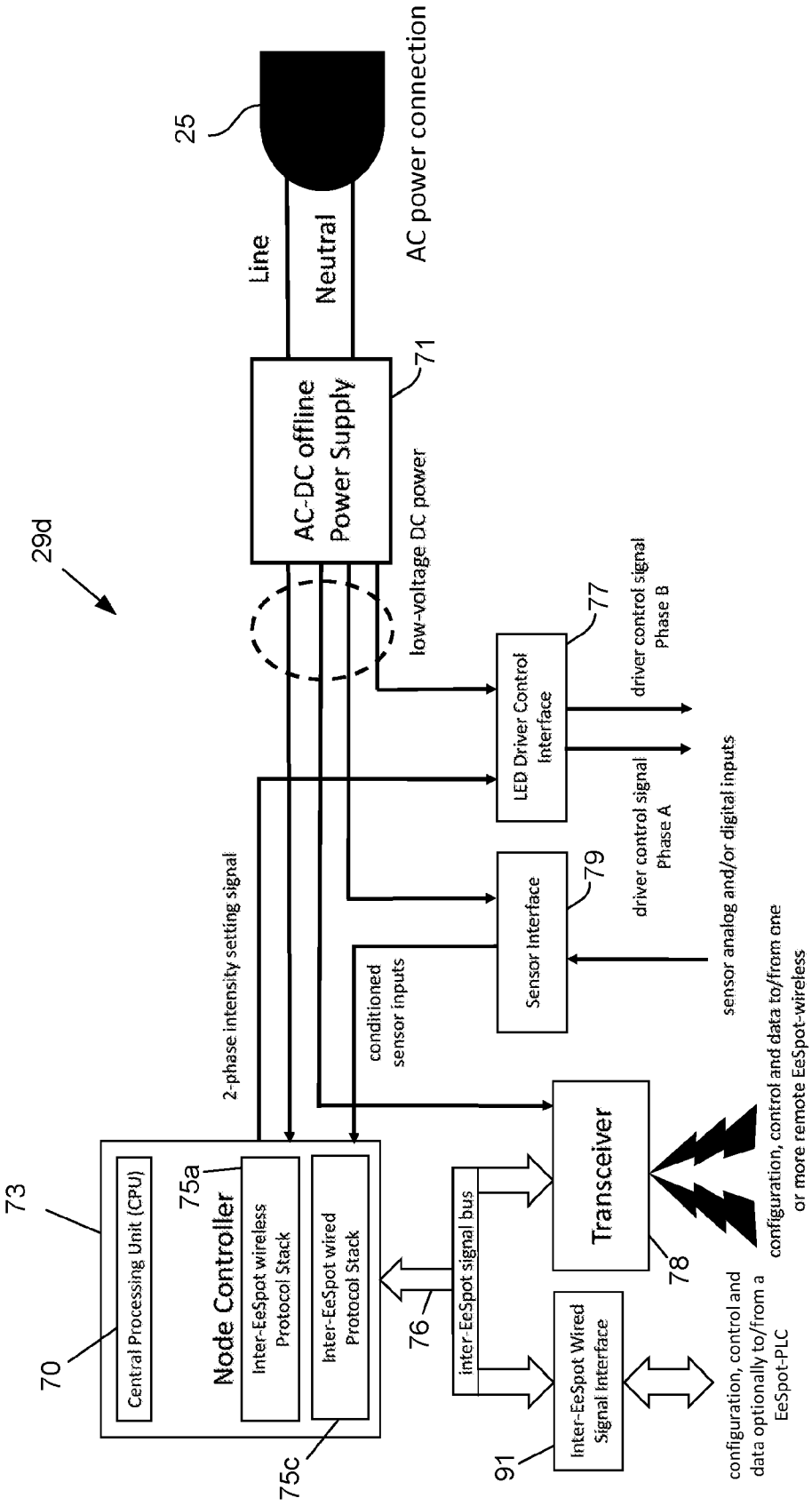
29d
25
AC power connection
Line
Neutral
AC-DC offline Power Supply
71
low-voltage DC power
LED Driver Control Interface
77
driver control signal Phase B
driver control signal Phase A
Sensor Interface
79
sensor analog and/or digital inputs
2-phase intensity setting signal
conditioned sensor inputs
73
75a
Node Controller
Central Processing Unit (CPU)
Inter-EeSpot wireless Protocol Stack
Inter-EeSpot wired Protocol Stack
70
75c
76
inter-EeSpot signal bus
Transceiver
78
configuration, control and data to/from one or more remote EeSpot-wireless
Inter-EeSpot Wired Signal Interface
91
configuration, control and data optionally to/from a EeSpot-PLC

FIG. 5

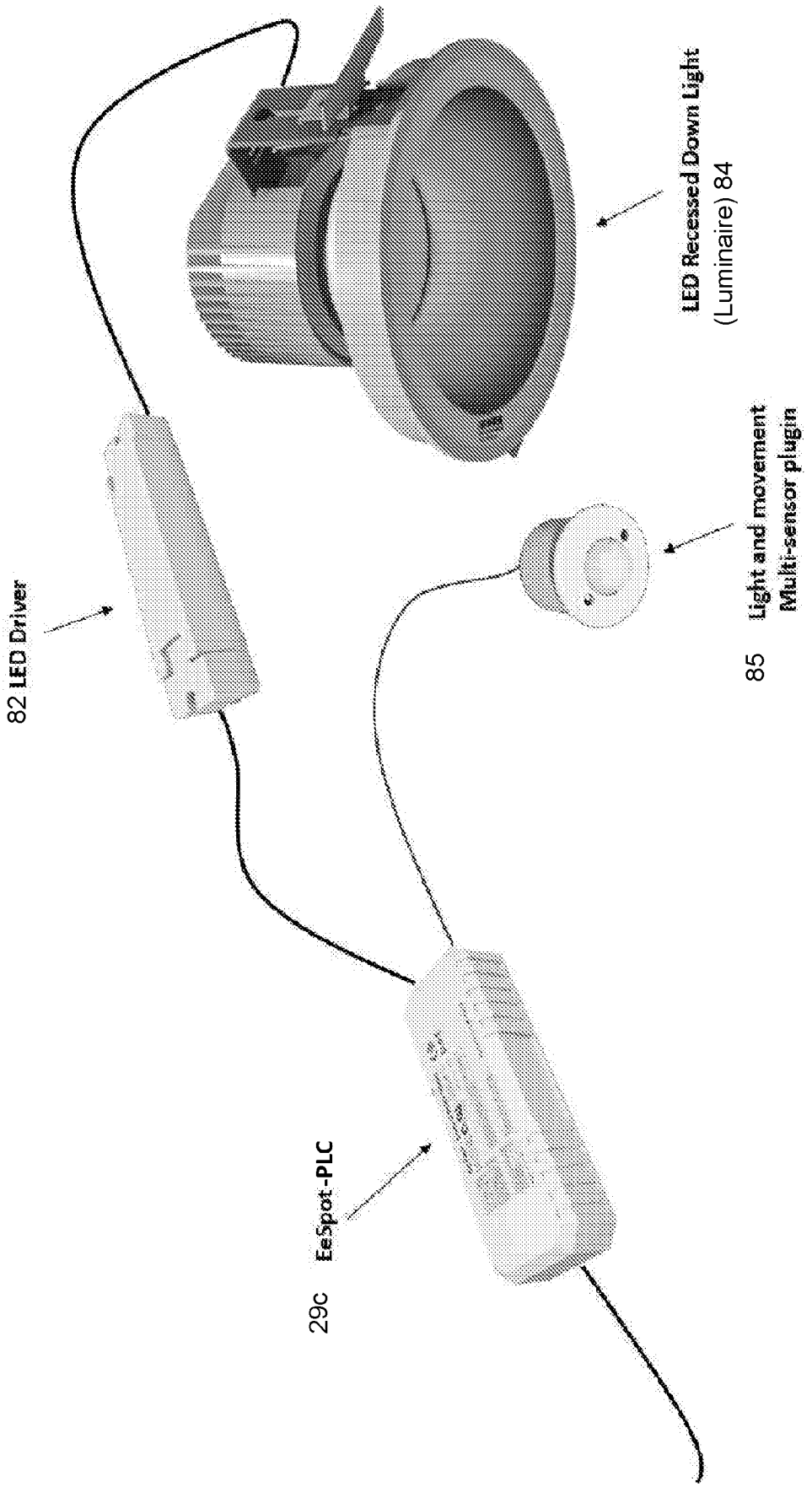
LED Recessed Down Light
(Luminaire) 84
82 LED Driver
85 Light and movement
Multi-sensor plugin
29c EeSpot-PLC

FIG. 6

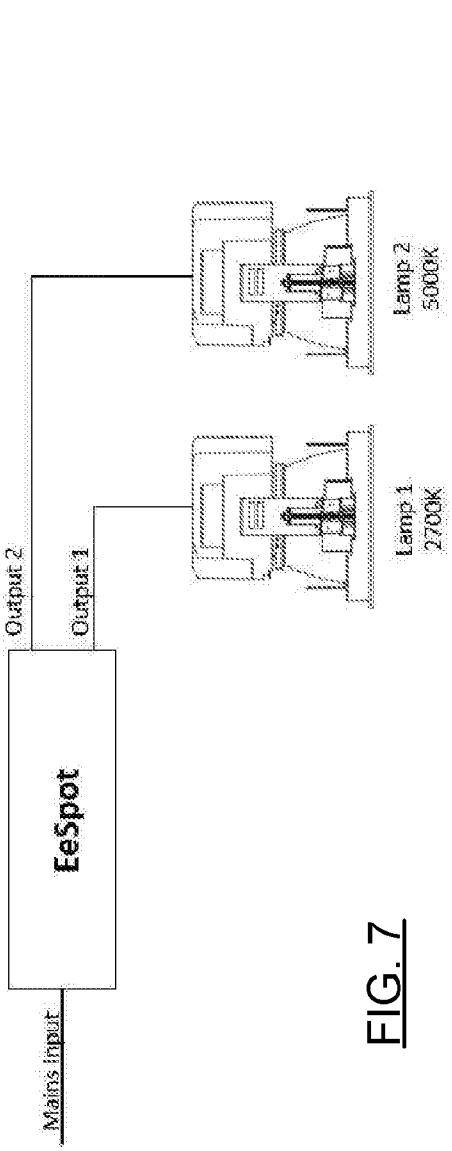
Mains input
EeSpot
Output 1
Output 2
Lamp 1
2700K
Lamp 2
5000K

FIG. 7

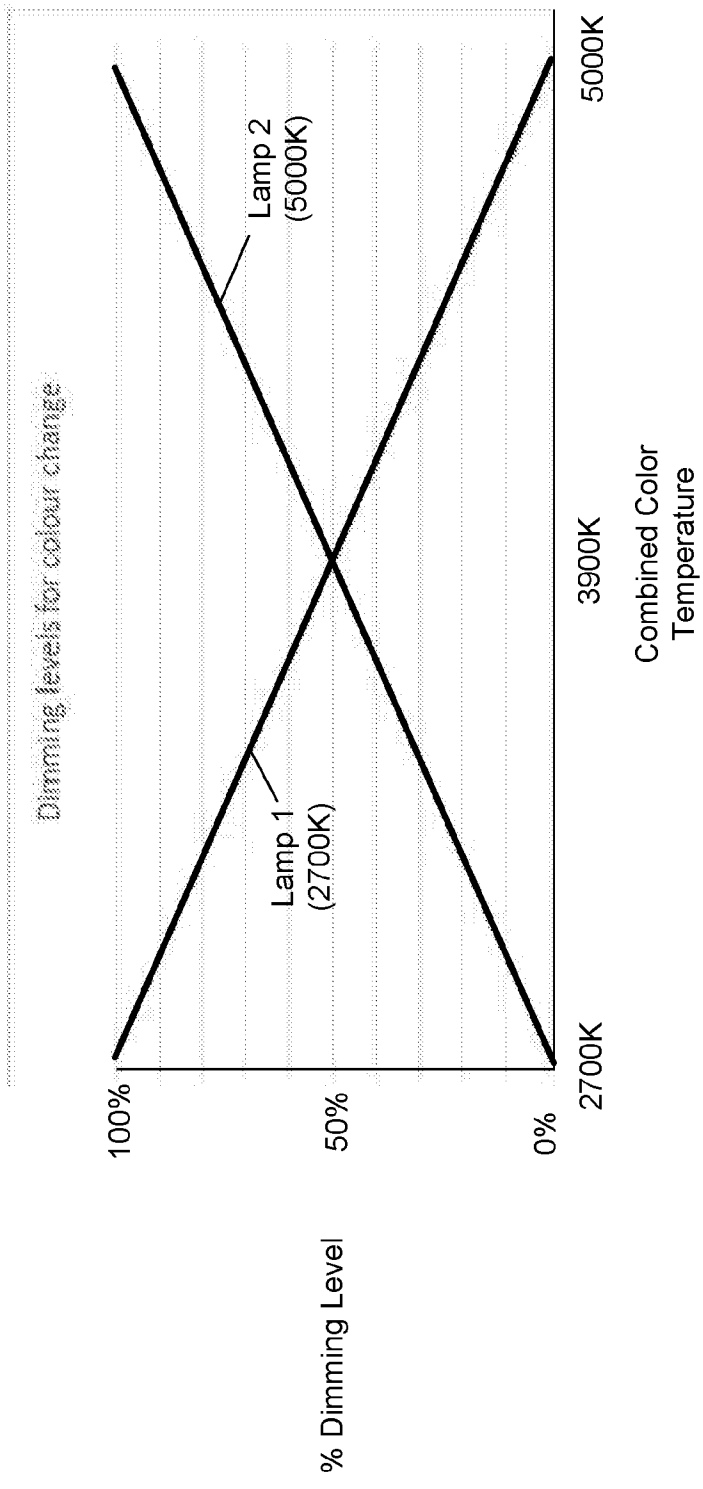
Dimming levels for colour change
100%
50%
0%
% Dimming Level
Lamp 1
(2700K)
Lamp 2
(5000K)
2700K
3900K
5000K
Combined Color
Temperature

FIG. 8

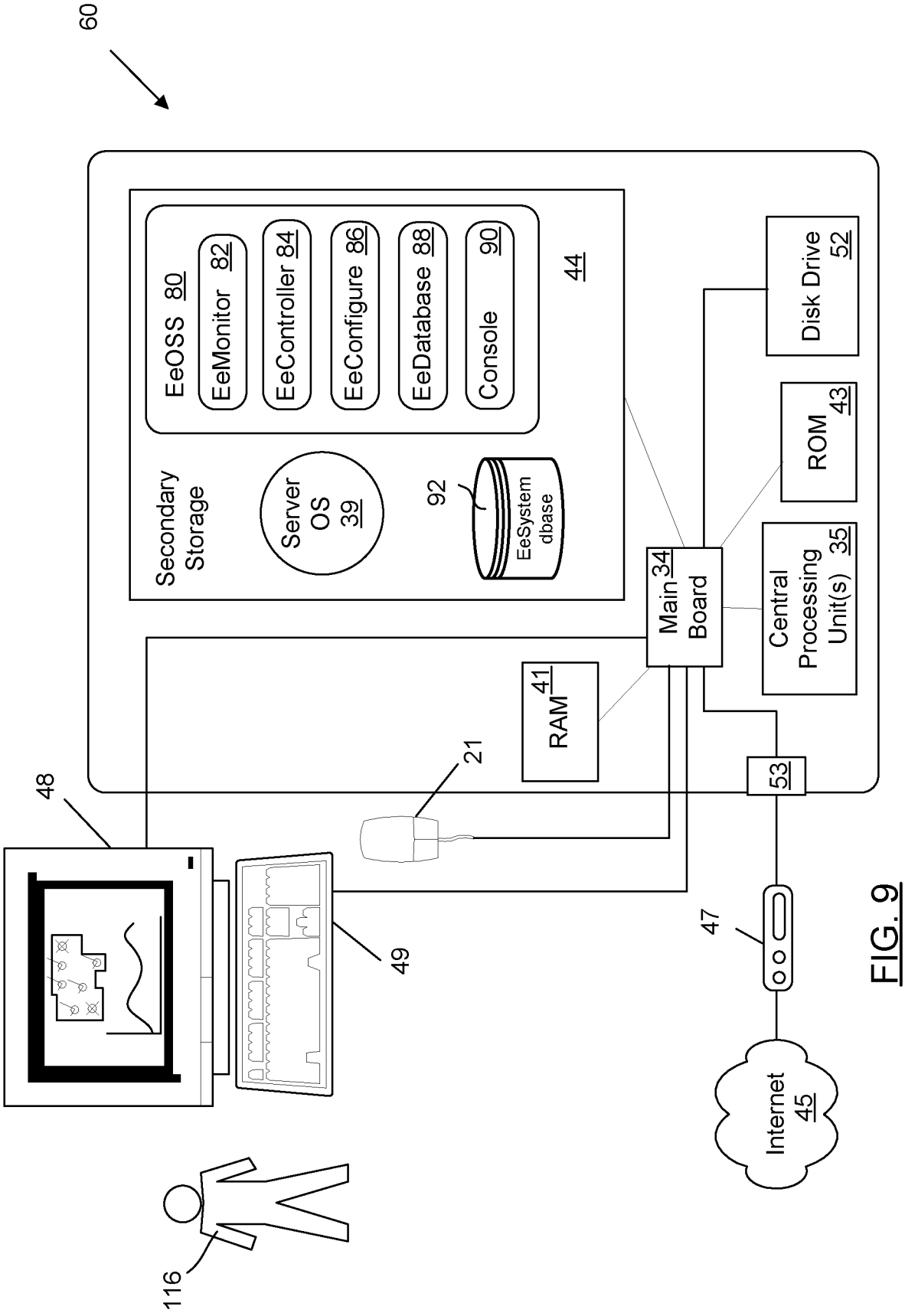
60
EeOSS 80
EeMonitor 82
EeController 84
EeConfigure 86
EeDatabase 88
Console 90
44
Secondary Storage
Server OS 39
92
EeSystem dbase
Disk Drive 52
ROM 43
Main Board 34
Central Processing Unit(s) 35
RAM 41
21
48
53
49
47
Internet 45
116

FIG. 9

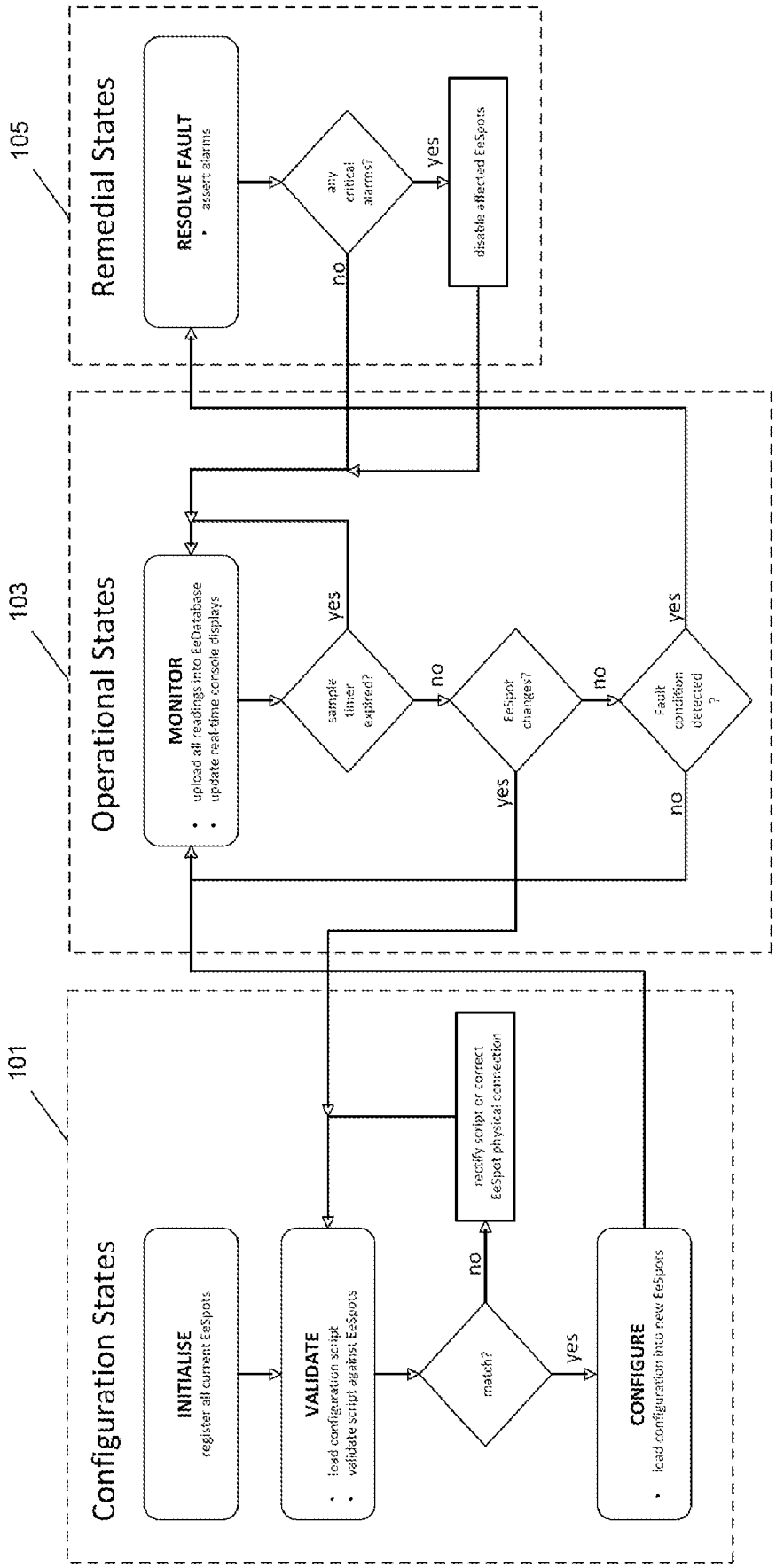
105
Remedial States
RESOLVE FAULT
• assert alarms
any critical alarms?
yes
no
disable affected EeSpots
103
Operational States
MONITOR
• upload all readings into EeDatabase
• update real-time console displays
sample timer expired?
yes
no
EeSpot changes?
yes
no
Fault condition detected ?
yes
no
101
Configuration States
INITIALISE
register all current EeSpots
VALIDATE
• load configuration script
• validate script against EeSpots
match?
no
yes
rectify script or correct EeSpot physical connection
CONFIGURE
• load configuration into new EeSpots

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2018/050065

A. CLASSIFICATION OF SUBJECT MATTER

H05B 37/02(2006.01)i

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)
H05B 37/02; H05B 33/08; H04B 3/54; H02J 13/00; H04B 10/116; H04Q 9/00; F21V 23/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: lighting, monitor, control, central computer, AC power network, PLC, hub device, powerline transceiver

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0271898 A1 (LUMENPULSE LIGHTENING INC.) 24 September 2015 See paragraphs [0008], [0012], [0022]-[0028], [0035], [0039]-[0043]; claim 1; and figures 1-6.	1-4,9,13-17
Y		5-8,10-12,18-23
Y	JP 2015-106828 A (KOIZUMI LIGHTING TECHNOLOGY CORP.) 08 June 2015 See paragraphs [0016] and [0043]-[0044].	5,18,23
Y	US 2011-0187275 A1 (ROD M. GILTACA et al.) 04 August 2011 See paragraphs [0026], [0036]-[0037], [0046], [0086]-[0088]; claim 1; and figures 1-2.	6-8,10-12,19-23
A	US 2015-0132006 A1 (RENESAS ELECTRONICS CORPORATION) 14 May 2015 See paragraphs [0102], [0115]-[0119], and [0137]-[0142]; claims 3, 6, 9, and 22; and figures 6 and 11.	1-23
A	US 2015-0137703 A1 (GENERAL ELECTRIC COMPANY) 21 May 2015 See paragraphs [0016]-[0025]; and figures 1-2.	1-23
A	KR 10-1208060 B1 (EDISON SOLITEC CO., LTD.) 04 December 2012 See claims 1-2.	1-23

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 July 2018 (06.07.2018)	**06 July 2018 (06.07.2018)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
NHO, Ji Myong
Telephone No. +82-42-481-8528

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2018/050065

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0057158 A1 (JACK YITZHAK JOSEFOWICZ et al.) 07 March 2013 See paragraphs [0089]-[0092] and figures 11-12.	1-23

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2018/050065

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU 238893 B2	25/05/2017
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2018/050065

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 2016-0113092 A1	21/04/2016
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		US 9439269 B2	06/09/2016
		US 9560720 B2	31/01/2017
		US 9622323 B2	11/04/2017
		US 9622324 B2	11/04/2017
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		WO 2015-077649 A1	28/05/2015
		WO 2015-077650 A1	28/05/2015
KR 10-1208060 B1	04/12/2012	None	
US 2013-0057158 A1	07/03/2013	CA 2791924 A1	09/09/2011
		WO 2011-106868 A1	09/09/2011