

A SYSTEM AND APPARATUS FOR PROVIDING AND MANAGING ELECTRICITYCROSS REFERENCE TO RELATED APPLICATION

[001] The application claims the benefit of United States Provisional Application Nos. 61/691786, 61/691791, 61/691799, 61/691801, and 61,781184, which are incorporated by reference herein in their entirety.

FIELD OF INVENTION

[002] The present invention is related to a system and apparatus for providing and managing electricity.

BACKGROUND OF THE INVENTION

[003] Electricity is an integral part of modern life. Whether in a personal home or a professional office, electricity powers appliances, tools and devices to provide a comfortable and convenient environment for people. However, as human population continues to grow, so has the demand for electricity. Concerned with how such insatiable demand and consumption impact the environment and cause sustainability issues, governments around the world have tried to raise awareness and to promote energy conservation and efficiency.

[004] The most common approach to energy conservation is to purchase and use energy efficient tools and appliances. While it is a good attempt to promote energy efficiency, there are several drawbacks. First, this approach relies too heavily on individual purchasing decisions and usage tendencies. Even when people have the best intentions to conserve energy and purchase energy efficient light bulbs and appliances, lights are often left on after office hours and appliances are persistently plugged in and sit idle between uses. Second, in many buildings, electricity usage in common areas is a necessity but most often less than optimized. Third, currently, there is no known way to monitor energy usage both on a macro level, such as a per floor, or a section of a floor or building, and on a micro level, on a per individual outlet basis to

identify inefficient points. Similarly, even when problems are identified, there is no easy way to communicate a patch to resolve the issue or to alter the usage pattern to quickly achieve the desired results.

[005] Accordingly, it is desirable to provide an improved system and method for monitoring and managing electricity that overcomes drawbacks and inadequacies of known methods and systems.

SUMMARY OF THE INVENTIONS

[006] Generally speaking, in accordance with the invention, a system provides a user with the ability to control devices connected to units within the system, even if the user is not physically near the devices. For example, the user may log in to the system from a cellular phone to monitor the energy usage of a specific device plugged into an electrical outlet unit, see whether or not the light is on in a certain room, or adjust the power of the ceiling fan in a specific room. The user may also be able to see reports on the energy consumption by a device, in a room, on a floor, etc.

[007] A system in accordance with a preferred embodiment of the invention includes a plurality of units, which communicate with one or more coordinators, which relays data from the units to a server, and relays commands from the server to the units. Alternatively, the coordinators themselves may initiate and send commands to the units. Preferably, the units have safety mechanisms to prevent overheating, fires, etc., by automatically shutting itself, or the device connected to it, off.

[008] The system preferably also includes energy saving protocols to reduce energy wasted. For example, the system may use light sensors or heat sensors to automatically adjust

the light or heat/air conditioning in a specific room or area by adjusting the current being provided to the respective device.

[009] An embodiment of the system also processes alerts from smoke detectors, motion detectors, carbon monoxide detectors, etc., to alert the user of a potential threat in the area in which such detectors are located.

[010] An embodiment of the system receives and tracks information about each device connected to each unit, including the expected energy usage or life of the device, and alerts the user of a deviation from such expectations. Therefore, if a device fails to meet its proposed energy usage or life, the user may either alert the manufacturer or avoid using the device in the future.

[011] An embodiment of the unit includes a plurality of circuit boards having components attached thereto, to provide power and detect energy usage of the connected device, sense the unit's internal temperature, sense or detect conditions surrounding the unit, process certain data collected by the sensors and detectors, as well as communicate with a coordinator. The unit preferably includes safety mechanisms to shut off automatically on its own, should it detect a fault.

[012] An embodiment of the unit includes an electrical outlet, via which electrical devices can be powered. Another embodiment of the unit includes a switch, via which one may turn on, turn off, or adjust the power being consumed by a device, such as the light fixtures in a room. Yet another embodiment of the unit includes a fixture unit, via which a fixture, such as a ceiling light or fan, is connected to its power source, preferably proximate the base of such fixture.

[013] An embodiment of the invention provides a system having a base unit and an interchangeable user interface. The user interface may be permanently or removably attached to the base unit.

[014] Yet another embodiment of the invention is a system providing a uniform electrical outlet for countries having differing plug configurations and RFI level requirements.

[015] Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification. Other features and advantages of this invention will become apparent in the following detailed description of exemplary embodiments of this invention with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[016] For a fuller understanding of the invention, reference is made to the following description taken in connection with the accompanying drawing, in which:

[017] FIG. 1 is a diagram showing a system in accordance with an embodiment of the invention;

[018] FIG. 2 is a diagram showing a system in accordance with an embodiment of the invention;

[019] FIG. 3 is an exploded perspective view of a unit in accordance with an embodiment of the invention;

[020] FIG. 4 is a perspective view of a unit and plugs in accordance with an embodiment of the invention;

[021] FIG. 5 is a perspective view of a unit and a variety of faceplates in accordance with an embodiment of the invention;

[022] FIG. 6 is a perspective view of an interchangeable system in accordance with an embodiment of the invention;

[023] FIG. 7 is a partially exploded perspective view of a unit in accordance with an embodiment of the invention;

[024] FIG. 8 is a partially exploded perspective view of a unit in accordance with an embodiment of the invention;

[025] FIG. 9 is a partially exploded perspective view of a unit in accordance with an embodiment of the invention;

[026] FIG. 10 is a partially exploded perspective view of a unit in accordance with an embodiment of the invention;

[027] FIG. 11 is an exploded perspective view of an electrical outlet unit in accordance with an embodiment of the invention;

[028] FIG. 12 is an exploded perspective view of a switch unit in accordance with an embodiment of the invention;

[029] FIG. 13A is a perspective view of a fixture unit in accordance with an embodiment of the invention;

[030] FIG. 13B is a perspective view of the fixture unit of FIG. 13A inserted into an electrical box;

[031] FIG. 14 is an exploded view of the fixture unit and electrical box of FIG. 13B with a ceiling fixture;

[032] FIG. 15 is a block diagram of an electrical outlet unit in accordance with an embodiment of the invention;

[033] FIG. 16 is a side perspective view of the electrical outlet unit of FIG. 15;

[034] FIG. 17A is a perspective view of a faceplate in accordance with an embodiment of the invention;

[035] FIG. 17B is a perspective view of a faceplate in accordance with an embodiment of the invention;

[036] FIG. 17C is a perspective view of a faceplate in accordance with an embodiment of the invention;

[037] FIG. 17D is a perspective view of a faceplate in accordance with an embodiment of the invention;

[038] FIG. 17E is a perspective view of a faceplate in accordance with an embodiment of the invention;

[039] FIG. 17F is a perspective view of a faceplate in accordance with an embodiment of the invention;

[040] FIG. 17G is a perspective view of a faceplate in accordance with an embodiment of the invention;

[041] FIG. 17H is a perspective view of a faceplate in accordance with an embodiment of the invention;

[042] FIG. 18 is a block diagram of a switch unit in accordance with an embodiment of the invention;

[043] FIG. 19 is a side perspective view of the switch unit of FIG. 18;

[044] FIG. 20 is a block diagram of a fixture unit in accordance with an embodiment of the invention; and

[045] FIG. 21 is a side perspective view of the fixture unit of FIG. 20.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[046] **System Overview.** Certain exemplary embodiments of the present invention will now be described with reference to the drawings. Reference is made to FIGS. 1-2, in which a system in accordance with certain embodiments of the invention is shown having a plurality of units 100, a plurality of coordinators 10, a router 20, a local server 30, a remote server 40 and a plurality of communication devices 50.

[047] The units 100 preferably interface with the energy consuming devices 60 in a facility. For example, the units 100 may be connected to lamps, light fixtures, appliances, televisions, fans, or a variety of other electrical units in a room, a house, or a floor of a building, by way of non-limiting example. In accordance with an exemplary embodiment, the units 100 can replace existing outlets and switches or be installed in light fixtures or fan controls, preferably designed and constructed to fit into a standard electrical box, thereby facilitating retrofitting of facilities.

[048] The units 100 preferably provide a variety of functions, for example, monitoring the energy usage of any device electrically connected thereto, turning the device 60 on and off, dimming it where appropriate, or otherwise monitoring or controlling the device. Each unit 100 monitors the amount of energy being drawn by the device 60 electronically connected to it. For example, if the device 60 is a lamp having two light bulbs and the energy usage at the unit 100 suddenly drops to half of what it was previously, it may indicate that one of the light bulbs blew out and needs to be replaced. An energy usage greater than expected for a specific appliance may indicate a flaw in the appliance.

[049] Generally, the units 100 may send data collected about the device 60 to one or more coordinators 10. For example, the unit 100 may send data regarding the device's energy consumption to the coordinator 10 regularly, or if the device 60 is suddenly drawing a

significantly greater or lower amount of energy, the unit 100 may send such data to the coordinator 10 regardless of its scheduled protocol.

[050] The coordinator 10 preferably processes most, more preferably all, the commands. Therefore, the commands can be processed and responded to more quickly than if one of the servers 30, 40 processed them. In certain scenarios, the coordinator 10 may receive data from the unit 100 and send a command in response thereto itself.

[051] In accordance with an embodiment of the invention, the coordinator 10 possesses the valid local network configuration and security controls. Therefore, the coordinator 10 may control local security to help assure the authenticity of devices attempting to join the network. In accordance with a preferred embodiment of the invention, each transceiver 132b of units 100 is assigned a unique media access control (MAC) address, preferably during hardware fabrication, and required to “join” the network. Joining is a secure process in which an authorized device is allowed to become a member of a Personal Area Network (PAN). The PAN ID is assigned by the coordinator 10, which keeps track of which units 100 are allowed on the network through their MAC addresses. The signals from the network are received and decoded by the transceiver 132b of the unit 100. Therefore, once a unit 100 is validated on the network, the free exchange of commands and data can commence. Also, assigning each transceiver 132b a unique address may facilitate identifying the units 100 when communicating therewith, for example, receiving data from or sending commands thereto.

[052] A system may have one or more coordinators 10 communicating with the local server 30 directly. Alternatively, in a network of coordinators 10 with a central coordinator, the coordinators 10 communicate with the central coordinator, which then communicates with the local server 30. In a preferred embodiment, each coordinator 10 manages up to 100 units 100.

The ratio of units 100 to coordinator 10 may be varied according to various factors, such as the volume and frequency of reports and response time desired, the layout of the facility, the type of equipment being connected to the units, etc. In accordance with an embodiment of the invention, a building may have one coordinator 10 per floor, to manage all the units 100 on the corresponding floor. The coordinators 10 either communicate with the local server 30 directly or via one or more other coordinators 10, using such other coordinators 10 as signal repeaters.

[053] The units 100 of the system may also include signal repeater units 500, acting as a bridge between the units 100 and the coordinator 10 to facilitate the transfer of data, commands, etc. therebetween. The repeater units may be used when the units 100 are located far from each other or from any coordinator. The repeater units 500 may be additional units 100 or modified units 100 without defined control functions or modified units 100 having transceiver 132b but having the control functions removed.

[054] According to one embodiment of the invention, units 100 and coordinators 10 are connected wirelessly, creating a wireless network. The wireless network connecting the units 100 and coordinators 10 is preferably a mesh network, wherein each unit 100 functions as a signal repeater and the coordinator 10 is the controller for all the units 100 in its network. Such a network may reduce the number of coordinators 10 or signal repeater units 500 necessary to facilitate data transmission between the units 100 and coordinators 10. An example of a wireless network suitable for an embodiment of the invention is a ZigBee® based wireless protocol. Once it received information, the coordinator 10 then relays the data wirelessly to the local server 30 via router 20. Whereas a wireless communication network is illustrated, it is to be understood that the coordinator 10 may be connected to the units 100, router 20 and/or the local server 30 via a wired connection, such as an Ethernet connection.

[055] Information and data collected by units 100 are passed to the local server 30. The local server 30 is running an operating system, preferably Windows® or Linux®, upon which the control and user application platforms run, and capable of running a web service to interact with the remote server 40 and other communication devices. In accordance with an exemplary embodiment, the control applications include a console based graphical user interface granting the users access to various levels of the system based on authorization. For example, a building administrator can specify and control lighting conditions for the entire building while individuals have access only to control functions in their office or immediate work area.

[056] In one embodiment, the local server 30 forwards the data or report received from Unit 100, or a report or alert created by local server 30 in response to the received data, to a user of the system via one or more communication devices 50. The user can then decide on a course of action. For example, the user may notice that a device 60 was unintentionally left on or plugged in and want to turn it off or reduce power being provided to it. The user can send the desired command to the local server 30, which in turn relays the command to the unit 100 to which the device 60 is electrically connected, via router 20 and coordinator 10. If the user wishes to turn the device 60 off, the unit 100 would stop the current flowing into the device. If the user wishes to reduce the amount of power being provided to the device 60, the unit 100 would reduce the current flowing into that device 60.

[057] As described above, the data may be relayed wirelessly, via a wireless local area network, such as WiFi, ZigBee® based wireless protocol or via an Ethernet cable or other wired connection, or a combination thereof. Whereas the embodiments of the system described herein refer to a wireless network, it is to be understood that a wired connection or other networking system is contemplated within the scope of the invention. It is also understood that compatibility

with wireless controlled appliances, whose industry standards protocol are under development, is contemplated within the scope of the invention. For example, the coordinator 10 or unit 100 may send the command directly to the device 60 so turn itself on or off.

[058] It is to be understood that the user need not reply to an alert or report from the system in order to take action. Rather, the user may use the communication device 50, such as a smart phone, computer, tablet, or any other device via which the user can communicate with the local server 30 or remote server 40, to send commands at any time. Whereas the system preferably promotes efficiency in energy consumption, there are numerous conveniences that it provides as well. For example, if the user forgot to turn off the stove, rather than rushing home, the user may check and send a command to turn off the unit 100 connected to the stove. The user may monitor whether or not the children are watching television or using the computer, etc. past their bedtime and shut them down remotely. If the sprinklers are scheduled to go off at a certain time but it is raining, the user may use the communication device 50 to command the unit 100 to turn off the sprinkler. If the user wants to cool his house before he gets home on a hot day, he may turn on the air conditioning unit or fan at the desired setting by adjusting the amount of power being provided to it. Whereas there may be systems currently available to perform some of these tasks remotely, the embodiment of the invention provides a system for controlling most, if not all, devices, so long as the devices are connected electrically or by a wired or wireless communication connection.

[059] The system may have a variety of settings requiring certain actions be taken when a condition is met. In an example of such a setting, if a unit 100 detects a device having a power factor of less than 90%, the unit 100 alerts the coordinator 10, which then relays the data to the local server 30, which notifies the user via a communication device 50. The user may request

the unit 100 to turn the device off or leave it as is. The same system setting could provide that if the unit 100 detects a device having a power factor of less than 75%, the unit 100 must turn the device off immediately, without waiting for instructions from the user. Another example of a system setting includes having a default time for dimming, for example, 30 seconds. Various other settings may be provided, such as energy savings modes, unit failure modes, and default action in case of network failure. For example, a unit 100 connected to a lamp or light fixture may be programmed to turn the lights on when the network fails and the unit 100 is unable to communicate with the coordinator 10 for over 60 seconds.

[060] Preferably, some units 100 have safety devices such that ground and arc faults as well as overheating can be detected and dealt with, preferably at the unit level without user input or commands from the coordinator 10 or local server 30 or remote server 40. For example, a unit 100 may include sensors to detect such conditions and alert the coordinator 10. The coordinator 10 is preferably designed and programmed to process the information, and if determined appropriate, command the unit 100 to shut down immediately. This may be preferred to speed up response time by eliminating the need to communicate with the server and/or user to determine what action to take, and a difference of seconds may be critical to whether or not a fire starts. Alternatively, unit 100 may have a mechanism to shut itself down automatically upon such fault or overheating, without waiting for a command from the coordinator 10.

[061] In addition to or as an alternative to the local server 30, a remote server 40 may be included in the system. In accordance with a preferred embodiment, the local server 30 analyzes the data received from unit 100 and generates reports, such as usage analysis reports. It then sends the data received, analyses and/or reports generated with respect to that unit 100 (collectively “unit data”) to the remote server 40. The remote server 40 may be a cloud server

connected via the Internet, which saves the unit data for access via the Internet or other means as a matter of application specific design choice. The remote server 40 may also analyze and process reports, such as periodic reports and energy savings information.

[062] Once the unit data is sent, the local server 30 would then be free to delete the unit data locally on a regular basis, which may speed up response time and reduce the storage necessary for the local server 30. However, it is to be understood that the system may include only one server, either local or remote, multiple local servers, multiple remote servers, or any alternate structure as desired, without deviating from the scope of the invention. For example, if a system has a local server 30 without a remote server 40, all system commands and data functions would be available at the local server 30, therefore the system could be contained within the boundaries of its firewall. Thus, the level of response and security may be improved. Additionally, the system would remain fully functional, including the reports and data being backed up and saved, even if there is no Internet connection. However, a large storage would likely be required, depending on the size of the system, which may be burdensome for smaller facilities. Some facilities may prefer a system having a remote server 40 without a local server 30, although such a configuration may delay response time. Accordingly, the number of local servers 30 and/or remote servers 40 may be varied as desired.

[063] **Units.** Units 100 generally include one or more boards 102. Units 100 may optionally include a front panel 120, and a faceplate 170. Preferably, unit 100 is constructed and designed to fit inside a single gang electrical box, for example, in a housing having a dimension of 3 inch by 2 inch by 2.5 inch. When a front panel 120 and the faceplate 170 are included in the unit 100, the front panel 120 is preferably positioned partially outside of the electrical box to

match the depth created by surrounding wall material, such as sheetrock, and the faceplate 170 covers the wall opening for the electrical box.

[064] **Boards.** Preferably, the boards 102 are circuit boards, such as a printed circuit board (PCB), a breadboard, a strip board or other structure suitable for electrically connecting components (collectively referred to herein as “circuit board”). Boards 102 may include a first board 130 and a second board 140. Whereas the embodiments illustrated show two boards 130, 140, it is to be understood that the unit 100, can have one board or more than two boards without deviating from the scope of the invention, as a matter of application specific design choice.

[065] The first board 130 and the second board 140 are preferably joined physically by a coupling mechanism, for example, one or more inserts or threaded standoffs. It is to be understood that the coupling mechanisms between the front panel 120 and the boards 102 or faceplate 170 may be the same or it may differ, without deviating from the scope of the invention.

[066] The first board 130 and the second board 140 generally include electrical connectors 105 and 106, which electrically connect first board 130 to the second board 140. These electrical connectors are preferably eight-pin headers and are located on each end of the boards 102.

[067] **First board.** Generally, the first board 130 also includes circuitry to carry out functions of the unit 100. For example, the first board may include a plurality of components including a Micro Controller Unit (MCU) 132a and an RF transceiver 132b that receives and decodes commands. In addition, the first board 130 may also include other components such as a GFI controller 132c, AFI controller 132d, program flash 132e, antenna 132f and an energy monitoring device 132g. These first components may be integrated or provided externally as

matter of application specific design choice. For example, antenna 132f may be integrated onto the first board 130 or provided externally.

[068] The MCU 132a processes most or all the control commands, and performs a plurality of functions. The MCU 132a and the transceiver 132b may be separate, as shown in FIG. 3, or integrated into a single circuit. If the MCU 132a and transceiver 132b are separate components, the communications therebetween preferably occur on a Serial Peripheral Interface Bus (SPI).

[069] In addition, MCU 132a is preferably capable of over-the-air programming by receiving such programming or system updates from the coordinator 10. The MCU132a may also store configuration parameters and current states for recovery via a program flash. In one embodiment, an energy monitoring device 132g is also included, which is preferably a special purpose integrated circuit, that measures and records voltage and current flows and calculates the active and apparent energy usage over a period a time. The energy monitoring device 132g may communicate with the MCU132a through the SPI.

[070] In addition to energy information, the MCU132a may also receive and process temperature information and monitor the temperature information for compliance under the conditions. If conditions are not in compliance, the MCU 132a may send a command to deactivate. The current flow and temperature may also be monitored and limited by the MCU 132a. The MCU 132a also may generate status indicators for digital or other display as appropriate.

[071] The RF transceiver 132b receives and decodes commands for the MCU 132a and allows the MCU 132a to communicate with the rest of the system, for example, with coordinator 10. An additional role of the transceiver132b may be to inform the MCU 132b upon a

prolonged loss of communications with the coordinator 10. The MCU 132a may then take appropriate action to indicate and address this state.

[072] The first board 130 may include a visible status indicator, for example, an LED indicator, visible through or outside of the faceplate 170. The LED indicator may have a plurality of colors or states each indicating a different status of the unit 100. For example, if the LED is off, it may indicate that the unit 100 is offline. A red LED may indicate a fault, and a flashing red LED may indicate an imminent fault. A green LED may indicate that the unit 100 is online and working properly, and a flashing green LED may indicate that the unit 100 is attempting to join or rejoin the network.

[073] Various environmental sensors, such as a light sensor, a room temperature sensor, a motion sensor and a carbon monoxide sensor, etc. may optionally be integrated on the first board 130. Depending on their functions, these sensors may or may not have corresponding apertures on the faceplate 170.

[074] **Second board.** The second board 140 preferably includes screw terminals 144, a power supply 145, and a plurality of components comprising various power sensing and controlling mechanisms. By way of non-limiting example, the plurality of second components may include voltage suppression/power converter device 142a, current sense coils 142b, control relay 142c, Triode for Alternating Current (triac) dimming control drivers 142d, and thermal sensor 146c.

[075] The second board 140 preferably includes a control relay 142c, which is a normally open double pole double throw mechanical relay designed to disconnect the load from the mains. The control relay 142c may respond to the normal on/off commands sent over the network or the fault signals from the MCU 132a, which generate a signal to activate or

deactivate the relay driver circuitry. It is to be understood that a solid state version of the relay is contemplated within the scope of the invention.

[076] The second board 140 may also include a triac circuitry comprising and a dimming control driver 142d and a dimming control triac 142e. The dimming control driver 142d is preferably an integrated circuit to amplify and translate the control signal out of the MCU 132a to drive the triac dimmer control 114. The dimming control triac 114 is preferably a semiconductor device capable of the controlled conduction of current in two directions, and therefore triacs may be preferred for use in alternating current dimming applications. A triac is controlled by a voltage pulse presented to the gate terminal of the device called a trigger. If this trigger pulse is synchronized with the start of the alternating current cycle, the device can be made to conduct on all or a portion of the cycle. By delaying the timing of the trigger pulse the duty cycle of the voltage and current waveforms are limited at the load, producing the dimming effect.

[077] The timing and duration of the gate pulse is preferably generated by the MCU 132a. The MCU 132a may receive a sync pulse generated on each zero crossing of the alternating current sine wave. This pulse starts an internal timer, which in turn generates the trigger at the time in the cycle required to produce the level of dimming specified. Shorter timing allows the dimming control triac 114 to conduct for longer in the cycle and therefore produce less dimming. Increasing the trigger delay time produces a larger dimming effect.

[078] The second board 140 preferably includes a heat sink 112. The heat sink 112 is preferably able to fully dissipate the maximum power in the dimming control triac 114 in the environment while maintaining a case temperature of less than 100°C. By way of non-limiting example, if the maximum power in the unit 100 is 23 watts for the dimming control triac 114, the

thermal resistance for the heat sink 112 is preferably less than 2.1 °C /Watt. The heat sink 112 may be mounted on the back of the second board 140 away from the first board 130, or it may be a separate piece from the second board 140.

[079] Generally, electricity enters the unit 100 from the power supply 145 through screw terminals 144 on the second board 140. Upon entering, power is conditioned by a voltage suppression/power converter device 142a. The voltage suppression/power converter device 142a is designed to reduce the amount of Radio Frequency Interference (RFI) which is reflected back on the mains. Devices with internal dimming circuits can generate large amounts of interference, and many countries require control on the magnitude of RFI generated by a dimming device. Therefore, it is preferred to reduce the RFI level, more preferably to meet or exceed the European Union (EU) requirements for Electrical Lighting and Similar apparatus – EN55015.

[080] The voltage suppression/power converter device 142a may be a metal oxide varistor (MOV). The literature shows 80% of all line transients have a duration between 1 and 10µS and amplitudes up to 1.2kV, which occur more than 10 times per day. Therefore the MOV device preferably has a voltage and energy rating capable of absorbing these transient without significant degradation over time. The MOV is preferably rated for a continuous 300 Volts AC with a clamping voltage of about 400 volts. Preferably, the energy rating is at least 50 to 75 joules.

[081] In one embodiment, the voltage suppression/power converter device 142a also includes a switching regulator, which converts the high AC voltage of the mains to a lower DC supply voltage to power. Preferably, the switching regulator is capable of generating 5 volts and 3.3 volts.

[082] The total current required from the low voltage switching regulator may be about 800 ma, with an output current of 1 ampere. Given the current requirements of the power converter switching regulator, there are several other factors to consider before choosing a circuit configuration. First, the regulator preferably interfaces directly from the mains, eliminating the need for a bulky transformer, which takes up space and may require personalization for different voltage configurations. Second, the output of regulator is preferably non-isolated, thus obviating the need for an internal isolation transformer and its associated cost and area. Third, given the high currents required, the regulator device is preferably mounted on a heat sink 112 to dissipate the power. Some or all of these factors may come into play in determining the final output specifications of the switching regulator. The voltage suppression/power converter device 142a can also includes low-dropout (LDO) regulator to convert the +5 volts to +3.3 volts for the MCU and wireless network radio components.

[083] The current invention may also include several safety features integrated into the unit 100. In one embodiment, several safety-related detectors are integrated into unit 100. For example, the second board 140 may optionally include an internal thermal sensor 146c, which preferably detects overload. In addition, two current sensing coils 142b monitoring currents may be included on the second board 140 to send signals to a Ground Fault Interrupter (GFI) controller 132c and Arc Fault Interrupter (AFI) controller 132d on the first board 130. Generally, a GFI circuitry may protect people from electrical shock from a fault appliance or an accidental insertion of an object into the outlet. An AFI circuitry may detect abnormal circuit conditions such as spikes and operating current.

[084] Generally, the GFI controller 132c on the first board 130 utilizes two sensing coils 142b on the second board 140 to monitor the current flow in the high line and the neutral line of

the main. These signals are amplified in an integrated circuit, which sends out a fault signal when the differential current exceeds 4 to 5 ma. As the GFI controller 132c monitors the amount of current flowing from hot to neutral, preferably it is able to sense a mismatch as small as 4 or 5 milliamps, and can react in milliseconds, thus removing the hazardous condition before harm can occur. If there is any imbalance, a signal is sent from the GFI controller 132c to the MCU 132a, which then trips a control relay 142c and removes drive to the circuitry.

[085] The AFI controller 132d also utilizes the signals from the sensing coils 142b, and detects abnormal circuit conditions such as spikes in operating current. These spikes can be caused by loose connection or damaged wire. These conditions not only waste energy, but they could eventually cause overheating and a fire. By monitoring the current flow and analyzing changes in conditions, the AFI controller 132d can also cause to trip the control relay 142c via MCU 132a to alleviate the hazard in case where abnormal conditions are recurring.

[086] The second board 140 may also include a thermal sensor 146c, for example a temperature sensor circuit. The thermal sensor 146c may be attached to the heat sink 112. Through the thermal sensor 146c, the MCU 132a can monitor internal temperature and signals a fault if the maximum operating temperature, for example, 90°C, is exceeded. This condition will deactivate the control relay 142c as a safety measure and send an alert to the system. The MCU 132a also monitors the expected temperature based on the current operating conditions and signal an alert if it is excessive.

[087] **Faceplate.** Unit 100 may also includes a faceplate 170, which may make unit 100 aesthetically pleasing, while providing a cover to protect the other components of the unit 100. The faceplate may be designed and constructed in different materials according to the desired use. For example, in one embodiment, the faceplate 170 may be made from plastic material as

used for conventional sockets. Faceplate 170 may have receiving portions 172 comprising apertures, which may or may not correspond to receiving portions on the front panel 120. The arrangement of these apertures depends on the location's electric system to receive different types of electric plugs with different pin arrangements.

[088] **Front panel.** The front panel 120 is preferably the interface by which the device 60 is electrically connected to the unit 100, and is positioned between the faceplate 170 and the first board 130 outside of the electric box. Alternatively, the unit 100 may include a front panel 120 without a faceplate 170. The faceplate 170 and front panel 120 may be separate pieces or be integrated into a single piece. In addition, the front panel 120 and the first board 130 may be joined physically by a coupling mechanism, for example, by one or more inserts or threaded standoffs. The front panel 120 and the first board 130 are preferably electrically connected by electrical wires. It is to be understood that the coupling mechanisms between the faceplate 170 and front panel 120 and between front panel 120 and first board 130 may be the same or may differ, without deviating from the scope of the invention. Additionally, the front panel 120 may be constructed and arranged to fit partially or wholly within the electrical box 600, as shown in FIGS. 4-8.

[089] The front panel 120 may comprise one or more receiving portions 122. Depending on specific application and design, the configuration of receiving portions 122 correspond to and align with receiving portions 172 on the faceplate 170 where applicable. The receiving portions 122 serve to receive cables, plugs, cords or other means by which power can be provided to a device attached thereto, such that the device can be electrically connected to the unit 100. By way of non-limiting example, the receiving portions 122 can be constructed and configured to connect to various devices or apparatuses. For example, receiving portions 122

may be a power plug outlets, Universal Serial Bus (USB) ports, mini-USB ports, micro-USB ports, HDMI ports, Ethernet jacks, and telephone jacks. It is to be understood that the receiving portions 122 may include any port or jack constructed and arranged to receive a desired cord, device, etc. as a matter of application specific to design choice and is not limited to the examples provided herein. Alternatively, one or more of such ports or jacks may be integrated into faceplate 170 or one of the boards 102 as a matter of application specific design choice. Preferably, such ports or jacks are isolated from the mains to avoid the mixing of high and low voltage wiring within the same box.

[090] The front panel 120 or first plate 130 may also include various environmental sensors, such as a light sensor, a room temperature sensor, a motion sensor and a carbon monoxide sensor. Depending on their functions, these sensors may or may not have corresponding apertures on the faceplate 170 and/or front panel 120. The light sensor may sense ambient light and facilitate the system making adjustments to optimize energy consumption while maintaining a certain level of illumination. For example, when there is a lot of sunlight coming into the room, the system may dim the lights connected to units 100 to achieve a certain level of illumination. As the day progresses and sunlight increases or decreases, the brightness of the lights may be adjusted accordingly to maintain the desired level of illumination. Such a system may maximize the use of natural light and eliminate energy being wasted on wasted light.

[091] The light sensor preferably can detect a luminance change range of 100 times, for example, from 0.02mw/cm^2 to 2mw/cm^2 . The room temperature sensor preferably detects and reports the temperature of the room or space in which the switch is located. Preferably, the effective temperature range is between 0 to 100 degrees Fahrenheit. The room temperature sensor may also be used to interface and control HVAC (heating, ventilation and air

conditioning) systems. The motion sensor preferably detects and reports the times and days of movements detected. Accordingly, the system may develop custom profiles for the location, which may facilitate anticipating customs and practices. The motion sensor preferably has a detection distance of about 10m or more, and a detection angle of greater than about 100 degrees vertically and horizontally. The carbon monoxide sensor preferably can detect from 1 ppm to 10,000 ppm and includes an internal alarm for immediate alert, and notifies the coordinator and preferably links to safety and security agents. Preferably, the carbon monoxide sensor has a response time of less than 60 seconds. Any of the sensors may or may not be built into unit 100. Alternatively, one or more of these sensors may be connected to unit 100 through one or more of the receiving portions 122.

[092] The front panel 120 may also include a visible status indicator, for example, an LED indicator, visible through or outside of the faceplate 170. The LED indicator may have a plurality of colors or states each indicating a different status of the unit 100. For example, if the LED is off, it may indicate that the unit 100 is offline. A red LED may indicate a fault, and a flashing red LED may indicate an imminent fault. A green LED may indicate that the unit 100 is online and working properly, and a flashing green LED may indicate that the unit 100 is attempting to join or rejoin the network. Preferably, the same boards 102 and other associated components may be used in various countries with mains of different electric voltages. More preferably, the same front panel 120 is used in the different countries as well, by providing receiving portions 122 capable of receiving plugs of the various countries, as described in further detail below and illustrated in FIGS. 3-6. Accordingly only the faceplate 170 would need to be country-specific to receive the standard electric plug of the country as needed. As shown in FIG. 4, the unit 100 may be used without a faceplate 170.

[093] Furthermore, in accordance with an embodiment of the invention, the boards 102 may be used with various front panels 130 having the contacts, interface, components, etc. to provide the desired function, thus providing a system of interchangeable front panels 130. In such a system, the same boards 102 may be installed in the electrical outlets of a building as well as in place of light switches and at the base of fixtures such as ceiling fans. Then, according to the desired use of the specified unit 100, the appropriate front panel 120 may be connected thereto. For example, a front panel having a power outlet interface may be provided by the bed for plugging in an alarm clock, a lamp, etc. Alternatively, a front panel having a switch interface may be provided in lieu of the power outlet interface, if the user wishes to have the switch located there instead of an outlet.

[094] In a toddler's room, it may be preferred to place a front panel having a power outlet interface higher above the ground to prevent the toddler from touching it. The electrical boxes proximate the floor of the toddler's room may have front panels 120 without any receiving portions 122 to help prevent the toddler from getting an electrical shock. Instead, the front panels 120 may have cameras to monitor the toddler. It is to be understood that any and all the front panels 120 may have cameras if desired, as a matter of application specific design choice. Preferably, the removal and attachment of the front panel 120 is simple enough for the user to rearrange the front panels 120 as desired, without requiring a new installation thereof.

[095] Alternatively, an embodiment of the invention as shown in FIGS. 5-6 provides a system in which the boards 102 and front panel 120 are suitable for various uses, just by replacing the faceplate 170 to a faceplate 170 for the specified use. A unit 100 may also include more than one front panels 120, as shown in FIGS. 5, 7-8. In the embodiments shown, a second front panel 120a connects to the front panel 120 outside of the electrical box 600. Such an

arrangement may be preferred in embodiments where the front panel 120 fits within the electrical box 600. The second front panel 120a as shown provides room for additional receiving portions, such as plug-receiving portions 122a, Universal Serial Bus (USB) ports 122b, mini-USB ports 122c, HDMI ports 122e, Ethernet jacks 122f, and telephone jacks 122g. In the embodiment shown, the second front panel 120a also includes a speaker 124 through which a user may speak to someone in the room in which the unit 100 is located.

[096] The unit 100 may also include a microphone by which the person in the room may speak to the user, or by which the user may listen to what is happening in the room. For example, if the unit 100 is in a baby's room, a grandparent living in another state or country may log into the system and watch and listen to the baby and speak to the baby as well, all via the unit 100. If the unit 100 includes an interface having a screen thereon, like an LCD screen as shown in FIGS. 9-10, the baby can see the grandparent's face and interact with the grandparent. Likewise, the unit 100 may be used as a means for video-chat with someone in the same facility via the local network or outside of the network via an internet connection.

[097] Front panel 120 may also include docking hooks or other connecting mechanisms to connect and power devices such as a phone, a cellular phone or tablet, turning the surface of the connected device into an interface control for the unit 100.

[098] Non-limiting examples of units 100 include an electrical outlet unit 200, a switch unit 300 and a fixture unit 400, as shown in FIGS 11-14. It is to be understood that unit(s) 100 refers to any or all electric outlet unit 200, switch unit 300 and fixture unit 400. Likewise, component(s) of units 100 refers to corresponding component(s) of electric outlet unit 200, switch unit 300 and fixture unit 400. For example, rear panel(s) 110 refers to any or all rear panels 210, 310, 410; front panel(s) 120 refers to any or all front panels 220, 320, 420; boards

102 refers to any or all boards 202, 302, 402; first board(s) 130 refers to any or all first boards 230, 330, 430; second board(s) 140 refers to any or all second boards 240, 340, 440; faceplate(s) 170 refers to any or all faceplates 270, 370, 470; transceiver(s) 132b refers to any or all transceivers 232b, 332b, 432b.

[0099] Preferably, the electrical outlet unit 200 replaces currently existing electrical outlets and fits inside a single gang switch box 600, for example, in a housing having a dimension of 3 inch by 2 inch by 2.5 inch, so that facilities with existing electrical outlets can be retrofitted with the electrical outlet units 200 in accordance with an embodiment of the invention. In accordance with an embodiment of the invention, the electrical outlet unit 200 can turn the device plugged into the electrical outlet unit 200 on or off, or dim it to an intermediate voltage level, for example, via a Triode for Alternating Current (triac) phase control.

[0100] Reference is made to FIGS. 11, 15-16, wherein an electrical outlet unit 200 in accordance with an embodiment of the invention is shown comprising a rear panel 210, one or more boards 202, a front panel 220 and a faceplate 270. In the embodiment shown, the boards 202 comprise a first board 230 and a second board 240. Preferably, the boards 202 are circuit boards, such as a printed circuit board (PCB), a breadboard, a strip board or other structure suitable for electrically connecting components (collectively referred to herein as “circuit board”) positioned behind the front panel 220. .

[0101] In the embodiment shown, faceplate 270 includes a plurality of receiving portions 272 which align with corresponding receiving portions 222 of the front panel 220 for receiving cables, plugs, cords or other means by which power can be provided to a device attached thereto, such that the device can be electrically connected to the electrical outlet unit 200. Referring to FIG. 11 and 16, the embodiment illustrated has two plug-receiving portions 272a in the faceplate

270 which align with two plug-receiving portions 222a of the front panel 220, each plug-receiving portion 222a constructed and arranged to receive a power plug, for example, to provide power to an electric device, such as a television, radio, toaster, lamp, computer, etc.

[0102] Other examples of receiving portions 222 include Universal Serial Bus (USB) ports 222b, mini-USB ports 222c, micro-USB ports 222d, HDMI ports, Ethernet jacks, and telephone jacks. It is to be understood that the receiving portions 222 may include any port or jack constructed and arranged to receive a desired cord, device, etc. as a matter of application specific to design choice and is not limited to the examples provided herein. Alternatively, one or more of such ports or jacks may be integrated into faceplate 270 or a board 202 as a matter of application specific design choice. Preferably, such ports or jacks are connected to the mains outside of the outlet box to avoid the mixing of high and low voltage wiring within the same box.

[0103] In accordance with the embodiment shown in FIG. 11, the front panel 220 includes plug-receiving portions 222a constructed and designed to receive various international configurations for a power plug, preferably most, more preferably all of the international configurations. Accordingly, the faceplate 270 may have plug-receiving portions 272a in specific international configurations. Examples of such faceplates 270 are illustrated in FIGS. 17A-H, wherein faceplate 270 is constructed and designed to receive plugs having the configurations for the Americas and Japan (FIG. 17A), most of Europe (FIG. 17B), India, Sri Lanka, Nepal and Namibia (FIG. 17C), Belgium, France, Poland, Slovakia, Czech Republic, Tunisia and Morocco (FIG. 17D), The United Kingdom, Ireland, Cyprus, Malta, Malaysia, Singapore, and Hong Kong (FIG. 17E), Australia, New Zealand, Papua New Guinea and Argentina (FIG. 17F), Switzerland and Liechtenstein (FIG. 17G), and Italy and parts of Northern

Africa (FIG. 17H). It is to be understood that FIGS. 17A-H merely show illustrations and that variations of faceplate 270 are contemplated.

[0104] Reference is made to FIG.16, in which the front panel 220 includes two plug-receiving portions 222a having electrical contacts 224 constructed and arranged to contact the prongs of a plug inserted into the plug-receiving portion 222a. The contacts 224 are preferably fed from three rails 225: the high rail 225a, the neutral rail 225b and the ground line 225c. In the embodiment shown, these rails 225 make connection to the mains, the power source, and ground through conventional screw terminals 244 located on the second board 240. The front panel 220 also includes a USB port 222b, an LED port 226a for a status LED, and additional ports 226b for powering a room temperature sensor, a light sensor, a motion detector or other mechanisms. Such sensors, detectors or mechanisms may be integrated into the front panel 220 or connected directly to the ports 226a, 226b. Alternatively, if such sensors, detectors or mechanisms are provided in the faceplate 270, the contacts for the ports 226a, 226b are arranged on the front panel 220 such that the corresponding sensors, detectors or mechanisms of the faceplate 270 electrically connect to the contacts. The contacts may then be electrically connected to the first board 230 via one or more electrical connectors 204. For example, the electrical connectors 204 may be a 10-pin header connection port. As one of ordinary skill in the art would understand, alternate mechanisms for electrically connecting the lines 225 to the mains, the components from the front panel 220 to the boards 202, and the first board 230 to the second board 240, are contemplated and may be used without deviating from the scope of the invention.

[0105] The first board 230 preferably includes circuitry to provide the functions described above. For example, the first board 230 may include a plurality of components, preferably a Micro Controller Unit (MCU) 232a, Radio Frequency (RF) transceiver 232b, GFI

controller 232c, AFI controller 232d, program flash 232e, antenna 232f and an energy monitoring device 232g. GFI controller 232c, AFI controller 232d process and interpret the detected signals from the GFI 246a and 246b, respectively. It is to be understood that the GFI 246a and/or AFI 246b may be separate or integrated into the sense coils 242b. The antenna 232f may be integrated unto the first board 230 or provided externally, as matter of application specific design choice. The first board 230 as shown is electrically connected to the second board 240 via electrical connectors 205, 206, preferably by eight-pin headers 205a, 206a on each end of the boards 202 to receive power from the second board 240.

[0106] Preferably, commands are received and decoded in the transceiver 232b. If the command is meant for the receiving unit, for example, if the MAC addresses match, the command may be acknowledged back to the coordinator 10 and passed on to the MCU 232a for execution. This bidirectional interface may facilitate the communications of commands and data between integrated circuits.

[0107] In accordance with a preferred embodiment of the invention, the MCU 232a processes most, more preferably all, the control commands, requests for data and response to sensors. The MCU 232a is preferably a 16-bit architecture capable of running at least a 16Mhz cycle time. The MCU 232a preferably performs a plurality of functions. By way of non-limiting example, the MCU may receive and process commands from the transceiver 232b and acknowledge command execution to the transceiver 232b. The MCU 232a may also receive energy data from the energy monitoring device 232g and relay the voltage, current and/or energy data to the transceiver 232b. The MCU 232a preferably calculates power factor and notifies the coordinator 10 if the power factor of the device connected to the electrical outlet unit 200 falls

below a specific value, preferably if the power factor falls below 0.8. The MCU 232a preferably also limits current flow based on the total wattage of the load.

[0108] The energy monitoring device 232g is preferably a special purpose integrated circuit which measures and records voltage and current flows and calculates the active and apparent energy usage over a period a time. The energy monitoring device 232g may communicate with the MCU 232a through a Serial Peripheral Interface Bus (SPI) port. In accordance with an embodiment of the invention, the MCU 232a queries the energy monitoring device 232g to report, receives the data and then passes it on to the transceiver 232b for communication with the system, for example, by passing it on to the coordinator 10. Examples of data monitored and reported on include, but is not limited to, demand line voltage, load current, active energy, apparent energy and accumulated energy. Room light level and temperature may also be reported. The ratio of apparent energy to active energy can be used to calculate the power factor of the load. When the power factor falls below a preset value, for example, below 0.8, the system may issue a warning and shut down the device connected to the electrical outlet unit.

[0109] Other possible functions of the MCU 232a include generating relay activate/deactivate commands based on data received from the network, for example, from coordinator 10. The MCU 232a is preferably capable of over-the-air programming by receiving such programming or system updates from the coordinator 10. The MCU232a may also store configuration parameters and current states for recovery via a program flash 232h. Preferably, the MCU 232a is expandable for further enhancements and additions to the electrical outlet unit 200.

[0110] The MCU 232a may receive and process line sync pulses 243 for the main interface driver, generate timed trigger pulses for dimming based line sync and dim set points and process line sync pulses 243 for the main interface driver, and modify the timing of dimming trigger pulses to produce different dimming profiles.

[0111] The main interface is an integrated circuit that optically couples signals from the mains to generate the sync pulse required by the triac circuitry. The coupler detects each time the main AC voltage crosses through zero volts and generates a positive output pulse. For a standard 60 cycle system, these occur every 8.33 milliseconds. These pulses are used by the triac dimming control driver 242d to determine the beginning of each dimming cycle and trigger the dimming control triac 242e accordingly.

[0112] The MCU 232a preferably receives, processes, and monitors internal temperature information of the electrical outlet unit 200 for compliance under the conditions, and translates to the control relay 242c to deactivate if not in compliance. The current flow and temperature may also be monitored and limited by the MCU 232a. Preferably, the electrical outlet unit 200 is capable of supporting up to 20 amps in an on/off application and 15 amps in a dimming configuration. The MCU 232a also may generate status indicators for digital or other display as appropriate. For example, the status may be “Connected” or “Fault.”

[0113] Whereas FIG. 15-16 show embodiments wherein the MCU 232a and the transceiver 232b are separate, it is to be understood that the MCU 232a and the transceiver 232b may be integrated into a single circuit without deviating from the scope of the invention. If the MCU 232a and transceiver 232b are separated, the communications preferably occur on a Serial Peripheral Interface Bus (SPI).

[0114] An additional role of the transceiver 232b may be to inform the MCU 232a upon a prolonged loss of communications with the coordinator 10. The MCU 232a may then take appropriate action to indicate this state. For example, if there is a loss of communication, the electrical outlet unit 200 may default to full on.

[0115] The first board 230 preferably includes a visible status indicator, for example, an LED indicator visible through or outside of the faceplate 270. Preferably, the faceplate 270 includes one or more apertures or lenses through which the LED indicator can be seen. The LED indicator may have a plurality of colors or states, each indicating a different status of the electrical outlet unit 200. For example, if the LED is off, it may indicate that the electrical outlet unit 200 is offline. A red LED may indicate a fault, and a flashing red LED may indicate an imminent fault. A green LED may indicate that the electrical outlet unit 200 is online and working properly, and a flashing green LED may indicate that the electrical outlet unit 200 is attempting to join or rejoin the network.

[0116] The second board 240 preferably includes a plurality of components, by way of non-limiting example, a power supply 245, voltage suppression/power converter device 242a, current sense coils 242b, control relay 242c, triac dimming control drivers 242d, dimming control triac 242e, and thermal sensor 246c. In accordance with a preferred embodiment of the invention, units 100, including electrical outlet units 200, switch units 300 and fixture units 400, comprise a common second board 140, which may facilitate manufacturing, installation and interchangeability of the units 100. The illustrated second board 240 also contains screw terminals 244 which electrically connect the electrical outlet unit 200 to the mains.

[0117] In the embodiments illustrated in FIG. 16, a heat sink 212 on which the triac dimmer 214 is mounted is attached to the back of the second board 240, preferably on the

opposite side of the second board 240 from the first board 130. The heat sink 212 is preferably able to fully dissipate the maximum power in the triac dimmer 214 in the environment while maintaining a case temperature of less than 100°C. By way of non-limiting example, if the maximum power in the electrical outlet unit is 23 watts for the triac dimmer 214, the thermal resistance for the heat sink is preferably less than 2.1 °C /Watt.

[0118] FIG. 15 provides a block diagram for an embodiment of an electrical outlet unit 200, illustrating its power path and signal path between the components. In the embodiment shown, power enters the electrical outlet unit 200 from the power supply 245, upon which it is conditioned by a voltage suppression/power converter device 242a. The device 242a is designed to reduce the amount of Radio Frequency Interference (RFI) which is reflected back on the mains by the electric outlet unit 200. Devices with internal dimming circuits can generate large amounts of interference, and many countries require control on the magnitude of RFI generated by a dimming device. Therefore, it is preferred to reduce the RFI level, more preferably to meet or exceed the European Union (EU) requirements for Electrical Lighting and Similar apparatus – EN55015.

[0119] The device 242a may be a metal oxide varistor (MOV). The literature shows 80% of all line transients have a duration between 1 and 10µS and amplitudes up to 1.2kV, which occur more than 10 times per day. Therefore the MOV device preferably has a voltage and energy rating capable of absorbing these transient without significant degradation over time. The varistor is preferably rated for a continuous 300 Volts AC with a clamping voltage of about 400 volts. Preferably, the energy rating is at least 50 to 75 joules.

[0120] The device 242a illustrated also includes a switching regulator, which converts the high AC voltage of the mains to a lower DC supply voltage to power the electrical outlet unit 200. Preferably, the switching regulator is capable of generating 5 volts and 3.3 volts.

[0121] The embodiment of the electrical outlet unit 200 also includes a USB charging port 272b. USB charging usually requires a handshake or enumeration between the host device (charger) and the USB device to be charged. This function may limit the charging current flow to the device depending on the level of charge required. The electrical outlet unit preferably utilizes an application specific integrated circuit to drive the USB port. Although the USB 3 specifications allow current draws of up to 2 amps, practical limitation (like the current limit of connectors) may limit the available current, for example, to 500ma.

[0122] In accordance with an embodiment of the invention, the total current required from the low voltage switching regulator is about 800 ma, with an output current of 1 ampere. Given the current requirements of the power converter switching regulator, there are several other factors to consider before choosing a circuit configuration. First, the regulator preferably interfaces directly from the mains, eliminating the need for a bulky transformer which takes up space and may require personalization for different voltage configurations. Second, the output of regulator is preferably non-isolated, thus obviating the need for an internal isolation transformer and its associated cost and area. Third, given the high currents required, the regulator device is preferably mounted on a heat sink to dissipate the power as in the illustrated embodiment of FIG. 16. Some or all of these factors may come into play in determining the final output specifications of the switching regulator.

[0123] The device 242a preferably also includes low-dropout (LDO) regulator to convert the +5 volts to +3.3 volts for the MCU and wireless network radio components.

[0124] As mentioned above, there are preferably several safety related detectors integrated into the electrical outlet unit 200. For example, electrical outlet unit 200 preferably includes a Ground Fault Interrupter (GFI) 246a and Arc Fault Interrupter (AFI) 246b as well as an internal thermal sensor 246c, which preferably detects overload. The GFI 246a may protect people from electrical shock from a faulty appliance or an accidental insertion of an object into the outlet. A GFI 246a monitors the amount of current flowing from hot to neutral. If there is any imbalance, it preferably trips the control relay 242c. Preferably, it is able to sense a mismatch as small as 4 or 5 milliamps, and can react in milliseconds, thus removing the hazardous condition before harm can occur. An AFI 246b detects abnormal circuit conditions such as spikes in operating current. These spikes can be caused by loose connection or damaged wire. These conditions not only waste energy, but they could eventually cause overheating and a fire. By monitoring the current flow and analyzing changes in conditions, the AFI 246b can also trip the control relay 242c to alleviate the hazard in case where abnormal conditions are recurring.

[0125] In the illustrated embodiment, the GFI 246a utilizes two sensing coils 242b to monitor the current flow in the high line and the neutral line of the main. These signals are amplified in an integrated circuit which sends out a fault signal when the differential current exceeds 4 to 5 ma. This signal is processed by the MCU 232a which opens the control relay 242c and removes drive to the triac circuitry comprising triac dimmer 214 and triac dimming control driver 242d. Since the triac is a fast-reacting device, the electrical outlet unit 200 preferably responds faster than conventional GFI circuits. Preferably, the response time is a few milliseconds as compared to 75 milliseconds in a conventional relay drive device.

[0126] In the illustrated embodiment, the AFI detector 246b also utilizes the signals from the sensing coils 242b. This signal is presented to the analog to digital converter input of the

MCU 232a. The digitized signals are processed by an auto correlation algorithm to identify the fundamental or periodic portion of the signal. Deviations from the expected or fundamental signal can now be analyzed for amplitude and repetitiveness. An intermittent fault caused by a defective connection, a frayed or broken wire can be detected. Because the processing requires complex analysis of the current wave forms to discriminate between a normal and abnormal operation, the MCU 232a may be busy processing other commands and functions, such as dimming functions and processing energy readings, and therefore may not be able to perform the AFI calculations and provide a real-time response, an auxiliary MCU may be included in unit 100 and be dedicated to perform the correlation calculations. After processing, the auxiliary MCU sends a signal to the main MCU 232a, which deactivates the control relay 242c and sends an alarm to the system, preferably through the wireless network.

[0127] In the embodiment shown, a thermal sensor 246c, for example, a temperature sensor circuit 246c, is included with a sensor diode attached to the heat sink 212. The MCU 232a monitors internal temperature of the electrical outlet unit 200 and signals a fault if the maximum operating temperature, for example, 90°C, is exceeded. This condition will deactivate the control relay 242c as a safety measure and send an alert to the system. The MCU 232a also monitors the expected temperature based on the current operating conditions and signal an alert if it is excessive.

[0128] The triac dimming control driver 242d is preferably an integrated circuit to amplify and translate the control signal out of the MCU 232a to drive the triac dimmer 214.

[0129] **Switch unit.** Reference is made to FIGS. 12, 18-19, wherein certain exemplary embodiments of the switch unit 300 are shown. The switch unit 300 preferably provides an interface for interaction with a user. For example, the switch unit 300 may have a manual switch,

such as a touch slide switch, a toggle switch, a push button switch, a membrane switch, a touch pad, a touch screen and any electronic device that may make or break an electrical circuit, constructed and arranged to control a device connected thereto, or a unit 100 in the system. For example, the switch unit 300 may be connected by conventional wire(s) to one or a group of lights, fans or units 100.

[0130] Preferably, the switch unit 300 replaces currently existing light switches and fits inside a single gang switch box 600. In accordance with an embodiment of the invention, the switch unit 300 can turn on or off or dim the lighting device electrically connected thereto.

Alternatively, if the switch unit 300 controls a different device, the dimming function may be used to reduce the power provided to the device. The switch unit 300 preferably also includes a thermostat function to monitor and control the temperature of the room in which it is located.

[0131] The boards 302 of the switch unit 300 may have some or all of the components of the boards 202 of the electrical outlet unit 200, preferably with additional components.

Alternatively, some of the components of the boards 202 may be excluded from boards 302 of the switch unit 300. As will be discussed below, boards 102 of units 100 in general may have the same components such that a user can simply place the desired front panel 120 to obtain the functions desired, providing a fully interchangeable system. In the embodiments shown in FIGS. 12, 18-19, the boards 302 of the switch unit include some, but not all, of the same components as the boards 202 of the electrical outlet unit 200 and also includes some additional components. Accordingly, some of the differences between the illustrated embodiments of the switch unit 300 and electrical outlet unit 200 will be discussed herein.

[0132] For example, the illustrated embodiments of switch unit 300 include a heat sink 312, an MCU332a, transceiver 332b, energy monitor 332c, program flash 332d, status indicators

332e, antenna 332f, voltage suppression/power converter device 342a, current sense coils 342b, triac dimming control drivers 342c, dimming control triac 342d, and thermal sensor 346, an LED port 326a for a status LED, and additional ports 326b, 326c for powering a light sensor 324a, a room temperature sensor 324b, a carbon monoxide detector 324c, a motion detector 324d or other mechanisms, screw terminals 344, wire connectors 304, electrical connectors 305, 306; but does not include a USB charging connection, a GFI 246a, an AFI detector 246b, control relay 242c and the associated components thereof. Therefore, if the MCU 332a, which monitors internal temperature, signals a fault indicating the maximum operating temperature is reached, the triac driver 342c is deactivated as a safety measure.

[0133] Similar to the electrical outlet unit 200, the transceiver 332b of the switch unit 300 preferably receives and decodes the commands. Some commands, for example, the on/off and dimming commands, may be received from the system over the local network to control either the triac dimmer 214 on the switch unit 300 or relayed to another unit 100 for execution.

[0134] The MCU 332a of the illustrated switch unit 300 performs the same functions as MCU 232a of the electrical outlet unit 200, except for relaying activate/deactivate commands and processing signals for GFI and AFI. However, the MCU 332a also responds to user input from the user interface 321 of the front panel 320, such as a touch pad 322, and displays status on the user interface 321, such as an LCD (liquid-crystal display) display 323. The LCD display 323 is preferably capable of displaying alpha-numeric characters and displays either the room temperature or the dim status. Additionally, MCU 332a translates signals from the system and displays the status on the touch pad 322 and/or relays the translated signals to joined units 100 as appropriate. The switch unit 300 may be connected via its dimmer to a load device, such as a

light fixture or a fan, and thus the energy utilized by this load device is preferably monitored and reported by the energy monitoring device 332c to the coordinator 10.

[0135] The MCU 332a illustrated also processes signals from one or more sensors 324, such as a light sensor 324a, a room temperature sensor 324b, a motion sensor 324c and a carbon monoxide sensor 324d, and transmits to the coordinator 10 for processing responses. The light sensor 324a may sense ambient light and facilitate the system making adjustments to optimize energy consumption while maintaining a certain level of illumination. Preferably the light sensor 324a can detect a luminance change range of 100 times, for example, from 0.02mw/cm^2 to 2mw/cm^2 . The room temperature sensor 324b preferably detects and reports the temperature of the room or space in which the switch is located. Preferably, the effective temperature range is between 0 to 100 degrees Fahrenheit. The room temperature sensor 324b may also be used to interface and control HVAC (heating, ventilation and air conditioning) systems. The light sensor 324a and temperature sensor 324b may be integrated into the front panel 320 or connected to the front panel 320 via port 326b. Alternatively, it is to be understood that the sensors may be integrated into or connected to the first board 330.

[0136] The motion sensor 324c preferably detects and reports the times and days of movements detected. Accordingly, the system may develop custom profiles for the location, which may facilitate anticipating customs and practices. The motion sensor 324c preferably has a detection distance of about 10m or more, and a detection angle of greater than about 100 degrees vertically and horizontally. The carbon monoxide sensor 324d preferably can detect from 1 ppm to 10,000 ppm and includes an internal alarm for immediate alert, and notifies the coordinator and preferably links to safety and security agents. Preferably, the carbon monoxide sensor 324d has a response time of less than 60 seconds. The motion sensor 324c, the carbon

monoxide sensor 324d and/or other components may be connected to the front panel 320 of the switch unit 300 via a port 326c, for example, a USB port.

[0137] **Fixture unit.** Reference is made to FIGS. 13A, 13B, 14, 20-21, wherein certain exemplary embodiments of the fixture unit 400 are shown. Similar to the embodiments of the electrical outlet unit 200 and switch unit 300 described herein, the fixture unit 400 is preferably powered off the mains and has universal connectivity to a wide range of voltages and generation frequencies. An embodiment of the fixture unit 400 fits into four by four square electrical boxes 600 currently available in the art and provides wireless control directly at the fixture 460. It has conventional on/off capability, complemented by three different modes of driving the dimming function: a standard dimming control triac 442e for traditional applications; an analog 0 to 10 dimmer 432g for dimming of electronic controllable ballasts and a pulse width control module (PWM) 432h for LED dimming. The fixture unit 400 may respond to wireless commands from the coordinator 10 or from a switch unit 300 to control the fixture 460 electrically connected thereto.

[0138] In accordance with a preferred embodiment, the fixture unit 400 has one or more of a smoke, carbon monoxide and motion detectors integrated into the fixture unit 400, either as standalone units or used in correlation with the fixture 460. The fixture unit 400 is preferably attached to the top of light fixtures. However, for fluorescent light fixtures, the fixture unit 400 is preferably mounted inside the troffer by the ballast.

[0139] The boards 402 of the fixture unit 400 may have some or all of the components of the boards 202, 302 of the electrical outlet unit 200 and/or switch unit 300, preferably with additional components. Alternatively, some of the components of the boards 202, 302 may be excluded from boards 402 of the fixture unit 400. In the embodiment shown in FIGS. 20-21, the

boards 402 of the fixture unit 400 include some, but not all, of the same components as the boards 202 of the electrical outlet unit 200 and also includes some additional components.

Accordingly, some of the differences between the illustrated embodiments of the fixture unit 400 and electrical outlet unit 200 will be discussed herein.

[0140] For example, the illustrated embodiments of fixture unit 400 include a heat sink 412, an MCU 432a, transceiver 432b, energy monitor 432c, program flash 432d, status indicators 432e, antenna 432f, an analog dimmer 432g, PWM 432h, smoke detector 432i, motion detector 432j, voltage suppression/power converter device 442a, current sense coils 442b, control relay 442c, triac dimming control drivers 442d, dimming control triac 442e, PWM driver 442f, analog dimmer driver 442g, an LED port 426a for a status LED, and additional ports 426b, preferably a USB port, for powering a smoke detector 432i or motion detector 432j or other mechanisms, a dim connector 428, screw terminals 444, wire connectors 404, electrical connectors 405, 406; but does not include a USB charging connection, a GFI 246a, an AFI detector 246b, and the associated components thereof.

[0141] The voltage suppression/ power converter device 442a is preferably the same as the device 242a of the electrical outlet unit 200, with an additional circuitry to generate a drive source for the LED and analog control signal voltages.

[0142] As mentioned above, the illustrated embodiment of the fixture unit 400 includes an analog dimmer driver 442g and an LED PWM driver 442h. The analog dimmer driver 442g is a separately generated DC control signal with a range of zero to ten volts, derived from a variable width pulse provided from the MCU 432a. This pulse is processed by a buck switching regulator to generate the voltage level requirements. The analog zero to ten volt dimmer will support a current source or sink of 200 milliamps. The LED PWM driver 442f is a constant

current source capable of driving loads up to 25 watts. It preferably utilizes a driver integrated circuit, which will be driven off the relay side of the mains and dimmed by pulses generated by the MCU 432a.

[0143] The transceiver 432b preferably receives and decodes commands, such as the on/off and dimming commands, which may be received from the coordinator 10 or a switch unit 300. In addition to the functions of the transceiver 232b of the electrical outlet unit 200, for embodiments having multiple configurations, the commands preferably control the on-board triac dimmer 442e, analog dimmer 432g or LED PWM dimmer 432h.

[0144] The MCU 432a of the embodiment of the illustrated fixture unit 400 performs the same functions as MCU 232a of the electrical outlet unit 200, except processing signals for GFI and AFI. However, the MCU 432a also processes signals from one or more sensors, such as a motion detector 432j and a smoke detector 432i, and transmits to the coordinator 10 for processing responses. The MCU 432a also generates timed variable duty cycle pulses to drive the analog dimmer driver 442g and LED PWM driver 442f, and modifies the timing of the dimming pulse widths to produce different dimming profiles.

[0145] The motion detector 432j preferably detects movements to activate lights or other trigger alarms. The information from the motion detector 432j may be stored and used to develop custom user profiles for the location. These profiles may be used to anticipate customs and practices. The motion detector 432j preferably has a detection distance of about 10m or more, and a detection angle of greater than about 100 degrees vertically and horizontally. The smoke detector 432i preferably includes an internal alarm for immediate alert, notifies the coordinator 10 and links to safety and security agents.

[0146] The examples provided are merely exemplary, as a matter of application specific to design choice, and should not be construed to limit the scope of the invention in any way.

[0147] Thus, while there have been shown and described and pointed out novel features of the present invention as applied to preferred embodiments thereof, it will be understood that various omissions and substitutions and changes in the form and details of the disclosed invention may be made by those skilled in the art without departing from the spirit of the invention. For example, the arrangement of the components, including which components are provided on which board or front panel or faceplate may be changed without deviating from the scope of the invention as a matter of application specific to design choice.

[0148] The communication system by which the units, coordinators and servers communicate may be varied as well. The system may be all wireless, all wired, or any combination thereof. The system may eliminate the coordinator and have the units communicate with the local or remote server directly. The system may eliminate the local server and have the coordinator process all the data and initiate commands to the units. The units may process the commands itself, as well as perform the other functions of the coordinator. The units may be configured to function as a wireless router to other devices in the network via which the devices can connect to other devices on the network or connect to the Internet.

[0149] The units may include a battery or some mechanism for retaining energy, so that the units can continue to function in the event of a blackout. The front panel itself may include a battery or some mechanism for retaining energy. For front panels having a communication mechanism, such as a microphone, speaker, screen, etc., a user may remove the front panel from the boards of the unit and continue using the communication mechanism thereof. Or, the front panel may be used as a portable charging dock, for example, for cellular phones, tablets, etc.

[0150] The units may include a surge protecting mechanism to protect the unit itself and/or the device connected thereto from a sudden surge in electricity. The faceplate or front panel may attach to the electrical box and not directly to the boards. The unit may include a housing in which the boards, or the boards and the front panel, or the boards, the front panel and the faceplate are housed, providing a unitary device.

[0151] It is to be understood that whereas the term “coordinators” is used herein, the referred to “coordinators” need not “coordinate.” Rather, a coordinator may be connected to a single unit, or have a single function, or varied in any way such that it may not be considered “coordinating,” without deviating from the scope of the invention.

[0152] Additionally, other alterations can be made, as a way of non-limiting example, the number of boards and the arrangement thereof, the number of front panels and faceplate, the removal or addition of boards or panels, the size thereof, can be varied, without deviating from the scope of the invention. Whereas the embodiments show boards being stacked one in front of the other, the boards may be positioned side by side, or have a panel or other component therebetween. A single board may comprise all the components of the first and second boards, and may be larger than existing electric boxes described above. For example, in new buildings without existing electrical boxes, it may be preferred for the units to have a different size and arrangement than the embodiments that fit into currently existing electric boxes.

[0153] Another contemplated embodiment of the invention includes the use of multiple front panels simultaneously on a common board(s), providing a modular system. For example, a front panel may cover a portion of the board while leaving portions of the board exposed, so that one or more other front panels may be connected thereto. An example of such a system includes front panels having country-specific plug-receiving portions. A hotel, for instance, may want to

provide outlets having multiple configurations. The unit therefore may include a front panel having one U.S. plug-receiving portion and another front panel having one European plug-receiving portion. According to where the visitor is from, the hotel may provide a front panel having the visitor's country-specific plug-receiving portion, as well as one front panel having a plug-receiving portion of the local configuration. Alternatively, a user may want a room light switch with an outlet or USB port. The user may attach a front panel having a switch interface and another front panel having a receiving portion onto the same unit. Such a modular system may provide multi-functionality to the unit and personalization, without being limited to the front panel configurations manufactured for the mass. Additionally, such a system may reduce manufacturing costs, since fewer configurations of the front panel may be necessary. It is to be understood that other combinations and configurations are contemplated without deviating from the scope of the invention. For example, the modular front panel may connect to a first front panel attached to the board(s) in a system having multiple stacking front panels as illustrated in FIGS. 7-8.

[0154] It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

[0155] It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

We claim:

1. An electrical management system comprising:
a plurality of control units, each comprising at least one circuit board configured to collect and transmit data and execute commands;
one or more coordinators; and
at least one server configured to receive data from at least one of said coordinators;
wherein the control units transmit data to at least one of said coordinators; and
wherein the at least one of said coordinators transmits said data to the server, receives a command from the server, and transmits said command to the control units.
2. The electrical management system of claim 1, wherein the at least one said coordinators initiates a command and transmits said command to the control units.
3. The electrical management system of claim 1, wherein the coordinator and the server are a unitary device.
4. The electrical management system of claim 1, the control units further comprising at least one safety mechanism to shut itself off automatically at certain conditions.
5. An electrical outlet unit comprising:
at least one board having a plurality of components; and
a front panel having a plug-receiving portion for receiving prongs of a power plug of an electrical device, the plug-receiving portion having a plurality of electrical contacts constructed and arranged to contact the prongs of the power plug when said power plug is received within the plug-receiving portion;
wherein the board connects to an electrical power source; and wherein the electrical contacts are electrically connected to the electrical power source, such that power flows to the

power plug and to the electrical device when the power plug is received in the plug-receiving portion.

6. The electric outlet unit of claim 5, comprising two or more circuit boards.
7. The electric outlet unit of claim 5, further comprising a transceiver to receive commands and a processor to process commands to control said electrical device.
8. The electric outlet unit of claim 5, wherein the board is designed and constructed to fit within a single gang electric box having an opening, and the front panel is designed and constructed to cover said opening of said electric box.
9. The electric outlet unit of claim 5, further comprising a faceplate having apertures corresponding to said plug-receiving portion of the front panel.
10. The electric outlet of claim 5, further comprising at least one sensor.
11. An electric outlet unit comprising:
 - at least one board having a plurality of components; and
 - at least one panel having a receiving portion for receiving a connection to an external device.
12. The electric outlet unit of claim 11, wherein the receiving portion includes jacks to receive a specific cord.
13. The electric outlet unit of claim 11, wherein the receiving portion includes a Universal Serial Bus (USB) port.
14. An electrical switch unit comprising:
 - at least one board; and
 - an interface by which a user completes or breaks an electrical circuit of a device connected to the electrical switch unit;

wherein the board connects to an electrical source and supplies power to the device; and

wherein the electrical switch unit controls the power supply to the device by completing or breaking the electrical circuit.

15. The electrical switch unit of claim 14, wherein the board is designed and constructed to fit within a single gang electric switch box having an opening, and the interface is positioned outside of said electric switch box, covering said opening.

16. The electrical switch unit of claim 14, further comprising a transceiver to receive commands and a processor to process commands to control the power supply to the device.

17. An electrical unit for fixtures comprising:

at least one circuit board having a processor and a transceiver;

wherein the circuit board is connected to an electrical power source and supplies power to a fixture connected to the electrical unit; and

wherein the transceiver receives commands and the processor decodes and executes said commands to control the fixture.

18. An interchangeable electrical unit system comprising:

at least one board having a first electric connector, the board configured to connect to an electrical power source;

a plurality of removable front panels having a second electric connector, the removable front panels comprising

an electrical outlet front panel having a plug-receiving portion constructed and arranged to receive a power plug, the plug-receiving portion having electrical contacts constructed and arranged to contact prongs of the power plug when said power plug is received within the plug-receiving portion; and

a switch front panel having an interface by which a user may control a device connected to the electrical unit; and

a locking mechanism constructed and arranged to maintain the board and at least one of the removable front panels at a fixed arrangement when in a locked position;

wherein the first electrical connector and the second electrical connector electrically connect the board and the removable front panel when in the locked position; and

wherein the locking mechanism is a releasable mechanism, such that the board can disconnect from one removable front panel and connect with another removable front panel.

19. An electrical unit comprising:

at least one circuit board having

a power component, which connects to an electrical power source to power the circuit board and any device electrically connected to the electrical unit; and

a processing component, which monitors power usage of said device.

20. The electrical unit of claim 19, further comprising a communication component to receive commands.