

SMART ELECTRICAL OUTLET/Socket DEVICE, SYSTEM, AND ASSOCIATED METHOD

TECHNICAL FIELD

[0001] This invention relates broadly to an electrical outlet/socket device, to a system for smart electrical power supply within a building.

BACKGROUND

[0002] The home automation industry is booming with smart products that promise higher convenience, comfort and even energy savings. Overall, what the smart products provide is a change in the life-style by changing the way humans do things. This is done through tasking electronic devices that can often communicate with a computing system (CS) which in parallel informs the humans/users. Besides informing humans, such a computing system could even inform yet another computing system performing different automations. These networks of technologies are broadly called as the Internet of Things (IoT).

[0003] Within home automations, there has been progress in the direction of developing remotely controllable electrical outlets or power plugs that can turn ON/OFF their electricity supply. A few of these plugs can even measure the energy consumption and relay that information to a display unit or their CS. Then the CS handles the job of aggregating and analyzing the information provided, and to carry out commands provided by the users. These plugs, along with their CS, get sold as “Smart Plugs” (SP) that augment the existing wall-mounted non-smart sockets. Example of a displaceable SP being used is shown in Fig.1. Seldom are they sold as wall-mounted sockets, probably due to the requirement of installation which makes their physical displacement or change in location difficult.

[0004] Currently, these existing plug/socket technologies get used in their full capacity at homes with a very few number of SPs assigned to the actual wall-sockets. The appliances then get manually assigned to such smart plugs. The pin-type of the SP sold depends on the standard followed by the country in which it is used, but there are no differences in the functions performed. Fig 2. shows an example of the same SP technology with different pin-types.

[0005] The combined operation of the SPs and their CS is shown in Fig 3. The gateway device may have embedded software in it that acts as a CS in itself; or the gateway device may relay the information to a computing device which contains the SP-managing software. The

SPs usually send their own connectivity status (available in the SP's communication network or not) and the energy consumption values to the CS. The CS typically can send the desired ON/OFF status to the SPs. Since most SPs rely on conventional wall-socket for their powering, turning OFF the wall-socket would make the corresponding SP unavailable for the CS.

[0006] This current system requires the consumer to place the purchased SPs strategically, manually assign each SP to a corresponding device via a software interface, and establish connection of SPs to the gateway. This task of assignment would be laborious if the number of outlets is many. Also, reassignments would be required when appliances get shifted to another electrical outlet. In a commercial building, multiple occupants could introduce different plug-loads in an ad-hoc manner, which makes appliance-to-SP mapping impractical for such a building.

[0007] Smart plugs that try to address this problem have been described in Elzabadani et. al. [Elzabadani, Hicham, A. Helal, Bessam Abdulrazak, and Erwin Jansen. "Self-sensing spaces: smart plugs for smart environments." In Proceedings of the 3rd International Conference on Smart Homes and Health Telematics, pp. 91-98. 2005].

[0008] The smart plugs described in Elzabadani et. al. have limited scope of identifying only the appliance-type corresponding to pre-existing java program the appliance carries as an OSGi bundle or the bundle's URL, which means that e.g. two appliances of the same category/type are not differentiated. Elzabadani et. al. proposes operation across multiple buildings using a centralized control system for all. Elzabadani et. al. bases operation on costly Phidget RFID (Radio-frequency identification) which is capable of only one-way communication and hence constrained. The smart plugs in Elzabadani et. al. lack electrical measurements and power-quality estimation abilities. Also, the smart plugs in Elzabadani et. al. lack physical security necessary for reliable smart-grid operations.

[0009] Other smart plugs are described in Ghazal et. al. [Ghazal, Mohammed, Muhammad Akmal, Shilpa Iyanna, and Kilani Ghoudi. "Smart plugs: Perceived usefulness and satisfaction: Evidence from United Arab Emirates." Renewable and Sustainable Energy Reviews 55 (2016): 1248-1259].

[0010] Gazahl et. al. uses ZigBee (meshed) protocol between plugs and requires a master-unit. Gazahl et. al. is a practical proposal only for a small space with a few nodes. The smart plugs described in Gazahl et. al. lack automated appliance identification.

[0011] Electric energy management devices are described in Zipperer et. al. [Zipperer, Adam, Patricia A. Aloise-Young, Siddharth Suryanarayanan, Robin Roche, Lieko Earle, Dane Christensen, Pablo Bauleo, and Daniel Zimmerle. "Electric energy management in the smart home: Perspectives on enabling technologies and consumer behavior." Proceedings of the IEEE 101, no. 11 (2013): 2397-2408].

[0012] Zipperer et. al. investigates at an abstract level the ideas for smart home, but proposes no hardware and doesn't consider the challenges in large buildings.

[0013] Embodiments of the present invention seek to address one or more of the above-mentioned problems.

SUMMARY

[0014] According to a first aspect of the present invention, there is provided an electrical outlet/socket device comprising a sensor for detecting the presence of an identification tag associable with an electrical appliance or plug-load, the sensor being configured for extracting a unique identifier of the electrical appliance stored in the identification tag; one or more electrical conductors configured for coupling to the electrical appliance for supply of power to the electrical appliance; a measurement unit coupled to the one or more electrical conductors for performing electrical measurements; and a processor configured for associating the electrical measurements with the unique identifier for further processing.

[0015] According to a second aspect of the present invention, there is provided a system for smart electrical power supply within a building, comprising an electrical outlet/socket device as defined in the first aspect; and a computing device configured for data communication with the electrical outlet/socket device; wherein the computing device is configured for processing data representing the unique identifier and the associated electrical measurements.

[0016] According to a third aspect of the present invention, there is provided a method for smart electrical power supply within a building, the method being performed using an electrical outlet/socket device, and the method comprising: detecting the presence of an identification tag that is associable with an electrical appliance, and extracting a unique identifier corresponding to the electrical appliance stored in the identification tag; performing electrical measurements; and associating the electrical measurements with the unique identifier for further processing.

[0017] In an embodiment of the present invention a new hardware-based digital mechanism is provided through an electrical socket that can uniquely identify each and every appliance

connected to it using near-field communication chips, thus generating context-aware electrical measurements through such identification. The features that can be achieved according to example embodiments include identifying the nominal electrical behavior of a particular appliance, its current operational electrical behavior, its history of physical locations where it was used, latest known time of operation, its ownership details (if associated), its price, manufacturing date, depreciation, and even its unique history of performance/usage. Such abilities make embodiments of the present invention truly know and recognize the appliance uniquely. Through its decentralized tagging of chips containing independently generated non-conflicting identifiers, embodiments of the present invention enable any human or organization to enable such appliance identification. As a concomitant aspect of example embodiments of the present invention, the electrical measurements analyzed through identification enable a building to perform online inventory management through corresponding software infrastructure. The scope of operations advantageously provided according to example embodiments include instantaneously knowing the list of appliances connected to the sockets of a building, their actual utilization rates/patterns, the safety testing and compliances certifications that the appliances have undergone, anomalous electrical behaviors or malfunctions, and even the genuineness of the appliances (counterfeit or not) – all in an automated fashion. Another aspect of embodiments of the present invention is the ability to allow/disallow electrical supply appliances in a building based on context-aware rules that depend on the features associated with the identity of the appliance – such as its design information, electrical operation, genuineness information, ownership information, and/or appropriateness during a time-span.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The invention will be better understood with reference to the detailed description when considered in conjunction with the non-limiting examples and the accompanying drawings, in which:

[0019] Figure 1 shows an existing smart plug/socket inserted in a conventional socket for receiving a conventional plug.

[0020] Figure 2 shows examples of existing smart plugs/sockets with different pin-types for different countries.

[0021] Figure 3 illustrates the combined operation of existing smart plugs/sockets and associated computer system(s).

[0022] Figures 4 shows a schematic diagram illustrating the low-power functional parts of a smart electrical outlet/socket according to an example embodiment.

[0023] Figure 5 shows a schematic diagram illustrating the ecosystem of multiple smart electrical outlets/sockets according to example embodiments managed by supervisory software.

[0024] Figure 6 shows a flowchart followed by a smart electrical outlet/socket according to an example embodiment.

[0025] Figure 7 shows a flowchart followed by local server for a smart electrical outlet/socket according to an example embodiment.

[0026] Figure 8 shows a flowchart followed by remote server for a smart electrical outlet/socket according to an example embodiment.

[0027] Figure 9 shows a comparison of a prototype a portable smart electrical outlet/socket according to an example embodiment and different existing sockets.

[0028] Figure 10A shows how an appliance tag is positioned with respect to a smart electrical wall-socket according to an example embodiment, with an NFC reader underneath in the body of the smart electrical wall-socket according to an example embodiment.

[0029] Figure 10B shows a more compact smart electrical wall-socket according to an example embodiment with appliance tag placed on the plug itself.

[0030] Figure 11A shows a database extract illustrating various data can be linked to any particular “*Appliance-Name*” corresponding to a unique identifier, according to an example embodiment.

[0031] Figure 11B shows another database extract illustrating various data can be linked to any particular “*Appliance-Name*” corresponding to a unique identifier, according to an example embodiment.

[0032] Figure 12 shows an extract from a database illustrating ratings and other information of multiple simultaneous appliances, and the real-time measurements of voltage, current, active power and energy, according to an example embodiment.

[0033] Figure 13 shows a sample circuit diagram of a smart electrical outlet/socket according to an example embodiment.

[0034] Figure 14A illustrates an example of the new functionality of customized electrical protection of plug-loads that example embodiments of the present invention can achieve as a sequence diagram.

[0035] Figure 14B illustrates an example of physical placement of SEOS hardware modules according to example embodiments within a building-grid.

[0036] Figure 14C illustrates an example of communication network corresponding to fig. 14B, according to an example embodiment.

[0037] Figure 15 shows a schematic drawing illustrating an electrical outlet/socket device according to an example embodiment.

[0038] Figure 16 shows a schematic drawing illustrating a system for smart electrical power supply within a building, according to an example embodiment.

[0039] Figure 17 shows a flowchart illustrating a method for smart electrical power supply within a building, according to an example embodiment.

DETAILED DESCRIPTION

[0040] It has been recognised by the inventors that the appliances/plug-loads connected within e.g. a building are categories by themselves, even though they are referred by their appliance-types such as “refrigerator”, “dish-washer”, etc. For example, there are many different manufacturing companies which produce products with the same common-name/type but with nuances in actual electrical behaviors that are controlled often by embedded electronics. This diversity makes them difficult to be accurately placed in existing classifications such as resistive load (R-load), resistive-inductive load (RL-load) and such. Also, this makes their mathematical analyses either difficult or too reductionist to be of any daily operational use.

[0041] It has also been recognised by the inventors that the classification of plug-loads into different power-ratings is also not viable always since the appliances could draw varying powers. For example, washing machines have electronics inbuilt in them that result in wash, rinse, spin cycles that draw different powers. While there have been attempts to empirically characterize home appliances using time-dependent power-curves [S. Barker, S. Kalra, D. Irwin, and P. Shenoy, “Empirical characterization and modeling of electrical loads in smart homes,” in International Green Computing Conference (IGCC). IEEE, 2013, pp. 1–10], they

do not account for the change in appliance behavior with respect to the e.g. manufacturer and product differences.

[0042] Embodiments of the present invention described herein entail electrical wall-socket and portable-socket hardware that are driven by corresponding software, the combination of which allows the socket to a) uniquely identify each and every electrical plug-load that gets plugged in to the socket hardware b) perform real-time voltage and current measurements c) perform active and reactive power, energy measurements d) identify power-quality events e) communicate digital data wirelessly to another machine with corresponding software f) perform on/off control of the electrical supply. The hardware abilities of the smart electrical outlet/socket (hereinafter SEOS) according to example embodiments enable a higher level intelligence that is unprecedented.

[0043] SEOS according to example embodiments can operate in the field of smart building management systems – the intelligence, automations and control associated with it. Example embodiments described herein are suitable for smart-grid operations so as to have economic savings, with novel context awareness and detail. The scope of operation for example embodiments described herein includes managing home appliances and appliances in commercial buildings – anywhere electrical sockets are useful. SEOS according to example embodiments can add new capabilities to the building management such as real-time appliance inventory, checking genuineness of appliances, location-finding of appliances, rule-based authentication for appliance usage at the socket (referred to hereinafter as *Building Firewall*), real-time predictive analytics on appliance performance and behavior, preventing standby/vampire loads, optimized and scheduled use of appliances, and many new digitalized business opportunities that are important in the setting of digital transformation and smart-grid evolution.

[0044] SEOS hardware according to example embodiments can exist in two general physical configurations – as a wall-socket and as a portable-socket (or plug), both providing the same intelligent functionality. Such embodiments are equivalent in their operations, with the physical casing and external connectors being different. The wall-socket is considered immovable by the common user after its installation, while the portable-socket is physically movable. SEOS hardware according to example embodiments preferably has Near-Field Communication (NFC) abilities to read information from tagged appliances that are less than

10cm away from it. SEOS according to example embodiments can have the following features and functions:

[0045] Load identification of tagged appliances – SEOS according to example embodiments can uniquely identify each and every appliance that are tagged using NFC tags/chips which provide different kinds of contactless communication methods and protocols at 13.56 MHz frequency. Since the tags can contain digital information that is uniquely different from one another, the corresponding appliances can also be uniquely identified when they are plugged into SEOS hardware according to example embodiments. As different kinds of information can be linked to the tag's information, this can enable the SEOS according to example embodiments to have access to them. Examples of digital information that can be linked to form a Digital-Profile for the appliance according to example embodiments include: a) Electrical Ratings and other specifications, b) Product description/price from manufacturer, c) Information on compliance certifications, safety tests, genuineness from relevant authority or manufacturer, d) Ownership information, e) Product's historical information on usage and performance, and f) Special information for smart-grid operations. In theory, any generic digital data can be linked.

[0046] SEOS according to example embodiments can utilize the identified information to monitor, track and schedule the appliances with an unprecedented intelligent awareness of what the exact appliance is and what its history is. Appliance scheduling is one of the emerging schemes smart-grid operations where the appliances are expected to operate only at intended times. It often implies plug-loads/appliances being operated in an optimized manner against time-varying electricity prices such that the building can do demand-response or demand-shifting. The objectives can include reducing overall energy consumed, or overall cost incurred, and/or keeping carbon footprint within certain limits. SEOS according to example embodiments can produce intelligence which makes scheduling realistic even in large buildings. With SEOS according to example embodiments it is possible to also restrict energy consumption. For example, a particular machine in an office can be scheduled to operate only on alternate working days. Or the appliance can be scheduled to operate only when a human-user reserves it for a particular time-slot. Since SEOS according to example embodiments can acquire real-time electrical measurements, it has access to present electrical state of the appliance and can log them digitally for future use. This can enable personalized billing as per consumption even in large buildings with multiple occupants.

[0047] Since the wall-mounted version of SEOS according to example embodiments is immovable for regular use, it provides mechanism to authorize the operation of an appliance based on digital information linked to the appliance. This is addressed as SEOS Building Firewall according to example embodiments which, in analogy to the firewall in popular computer operating systems, enables to use rules to define socket-behavior, such as allowing/prohibiting certain appliances. For example, since user information can be attached to a digital-profile, certain users and/or appliances can be authenticated (or denied), thus enabling access control of electrical power through sockets. For instance, guest-appliances of guest-users could be allowed in a building only if they are below certain power rating. A one-time task of location assignment for wall-sockets can also be present in SEOS according to example embodiments. For a large building, it may be preferred to programmatically extract the location of its many (e.g. hundreds) sockets into a file and auto-generate location indicators using that configuration file. In other embodiments, a geographic information system (GIS) interface of SEOS preferably operates in that manner.

[0048] Since appliance operation can be monitored, certain anomalous appliance behavior of an already authenticated appliance can be contextually identified. For example, appliances which are exceeding their expected electrical currents could be reported to the building operator and/or the appliance's owner. If an appliance has multiple modes of operation that draw different currents, like a washing-machine with wash, rinse, spin cycles – such an appliance can be suitably monitored and reported differently.

[0049] These features of SEOS according to example embodiments exist on top of the basic abilities expected of the modern SPs to communicate wirelessly with its CS. SEOS hardware according to example embodiments is an electrical outlet that can be packaged in two forms for a given pin-configuration followed in a country – wall-socket and portable-socket, as mentioned above. The low-power functional parts which provide the smartness to SEOS, 400 according to an example embodiment, are shown in fig. 4.

[0050] It is noted that the electrical conductors that typically allow connection between the appliance and the electrical supply of a building, which conventional wall-sockets and extenders already have, have been omitted in fig. 4.

[0051] Numeral 402 - An apparatus for measurement of electrical parameters (voltage, current, their waveform characteristics, active power, reactive power, energy etc.) in real-time using an IC (integrated chip) that is fed by voltage and current sensors. Note that the voltages

and current sensors sense instantaneous values of electrical parameters, which would include power-quality information too, according to example embodiments.

[0052] Numeral 404 - A relay which allows turning ON and turning OFF of electrical power through the conductors.

[0053] Numeral 406 - A near-field communication (NFC) reader which can read near-field communication tags or chips that comes within 5-10cm proximity of the reader. The communication takes place at 13.56 MHz. In one non-limiting example, an NFC tag reader with the NFC controller PN532 for NFC tags that use NTAG213 chips can be used.

[0054] Numeral 408 - A communication module which can transmit and receive data. Typically, Wi-Fi is used because it has become common in the indoor environment. It is noted that there are alternatives that are common in the IoT (Internet of Things) domain such as ZigBee, Bluetooth, ZWave etc.

[0055] Numeral 410 - A processor or computing hardware which handles the operation of the IC, the relay, the near-field reader and the communication module. This part is the local brain of the SEOS hardware according to example embodiments which handles the digital identification of appliances through the other components.

[0056] The ecosystem 500 of SEOS according to example embodiments would have multiple SEOS hardware e.g. 502 managed by supervisory software, as depicted in fig. 5. When an appliance e.g. 504 is plugged in to SEOS hardware e.g. 502, with its NFC tag/chip (not shown) being placed on or near the plug e.g. 506 of the appliance e.g. 504, the information in the tag is communicated to the near-field reader (not shown) of the SEOS hardware e.g. 502. That information is acquired by the processor through serial data transfer. The processor also acquires real-time contextual measurements through the metering IC. This data is sent to the local SEOS server 508 wirelessly. The appliance's tag information helps the local SEOS server 508 to gather the context and instruct the SEOS hardware 502 regarding the parameters to be measured and computed. For example, an electrically sensitive appliance might require voltage to be measured more frequently and checked for a narrower band of voltage deviation. The local SEOS server 508 can instruct the SEOS hardware e.g. 502 to set that frequency and tolerance band, as and when the particular sensitive appliance is encountered. Since Wi-Fi is used in this example embodiment, a router 510 functioning as per IEEE 802.11 specifications is shown within fig. 5.

[0057] A remote server 512 is shown which is capable of serving local servers such local SEOS server 508 of multiple buildings. In this example embodiment, the remote server 512 is a website that can resolve the digital-profiles of the appliances based on the querying that a local SEOS server 508 does using the tag information read by SEOS hardware e.g. 502. Such querying is done for example when the local SEOS server 508 does not have the digital-profile of the appliance stored in its own local database. The remote server 512 provides a website or web-service accessible to at least three kinds of users according to an example embodiment—manufacturers, individual appliance-owners and buildings – through mobile devices (smartphones/tablets) or computers (laptops/desktops) 514. In this example embodiment, remote server 512 acts primarily as a global registry of appliances. In a secure manner, manufacturers can add all the details that they can provide towards the digital-profiles of the appliances that they manufacture. Ideally it includes serial numbers of each and every electrical appliance that they manufacture, coupled with the appliance details. The individual appliance-owners can claim a particular appliance and are free to link their ownership information to the digital-profile. Once claimed, they can make requests and queries regarding their appliances. Remote-server 512 allows the appliance-owners to set permissions/authorizations as to who can access their ownership information regarding their appliances. For example, an appliance-owner could allow own office building to access the list of that individual's personal appliances kept in the office so that the Building Firewall can allow those appliances. An organization or a building can use their local SEOS server 508 to interact with the remote server 512. This could be to query about an appliance or to submit appliance information securely. If the manufacturer is the one doing the tagging of the appliance, they can use the security features of modern NFC tags to protect certain information. The features of the tag along with the information in the tag can be used as a useful method to check genuineness of an appliance. That means, an appliance encountered by the local SEOS server 508 can be checked using remote server 512 whether the appliance is genuine and claimed by an owner. This process would provide more certainty if the retailer provides the information to the remote server 512 regarding the appliances that have already undergone the sale. It is important to note that the remote server 512 and its devices 514 connecting to it are optional. Alternatively, the remote server 512 could be used to perform the tasks of SEOS local server 508, in case the local server is absent. Details of remote server 512 indicate the new possibilities that SEOS according to example embodiments open up. The local SEOS server 508 provides digitalized services to the

building occupants and the building-operators through wired/wireless Local Area Networks (LAN) in example embodiments. In this example embodiment, web-applications that can run on mobile devices (smartphones/tablets) or computers (laptops/desktops) 516 act as clients for the local SEOS server 508. Examples for the services will be described in more detail below. Through its multi-processing and multi-threading capabilities, local SEOS server 508 acts as server for SEOS hardware 502 and also the programs/applications in 516.

[0058] Fig. 6 shows the flowchart 600 followed by SEOS hardware e.g. 502 according to example embodiments. The flowchart in fig.6 performs three tasks 602, 604, 606 in a multi-threaded manner such that they happen in parallel on an average within a time-duration. The processor in the SEOS hardware 502 is preferably fast enough to execute the steps shown in fig. 6 within milliseconds. It polls the NFC reader 406 whether a tag is present or not 608. Meanwhile, it also checks 610 whether the electrical current measured is above a small threshold value (I_0) so that it can ensure that some plug-load is drawing current. It is to be noted that the appliance could be physically connected but not drawing any current (i.e. it is in the OFF state). When the appliance tag is read 611, the data is sent 612 to local SEOS server 508 to determine the appliance's digital-profile, and the local SEOS server 508 commands/instructs the SEOS hardware 502 to switch ON after checking its database and the Building Firewall module. There are auxiliary commands that can be sent 614 to SEOS hardware 502 by the local SEOS server 508 according to example embodiments, such as instructing the processing unit of the hardware to check for electrical current's violations from the expected value extracted from the digital-profile and toggle the power relay if a violation is determined 616, 618 resulting in OFF state of the electrical supply. Or the auxiliary instruction could be to obey the command of the local SEOS server 508 and toggle relay 616 to change relay state 618 so that the electrical supply is turned ON. In a looped fashion, the SEOS hardware's 502's processing unit acquires the electrical measurements 620 that are determined as "required values" by the local SEOS server 508. Typical values are real-time root-mean-square voltage (V), corresponding current (I), active power (P) and energy (E). This is not an exhaustive list of measurements since the number of different measurements that a metering IC can do would run into dozens. Based on the appliance identified, local SEOS server 508 decides the parameters to be measured by SEOS hardware 502. For example, if an appliance is inductive or capacitive, there might arise a need to measure reactive power. But for the resistive plug-

loads, that parameter can be avoided and the communication network will have fewer numbers of bytes to transfer to the server.

[0059] The flowchart 700 of SEOS local server 508 according to an example embodiment is shown in fig. 7. It preferably uses multi-processing 702, 704 so as to decouple its reaction-speeds towards the two types of clients that it serves – the SEOS hardware 502 modules (say, total count of n) and the client programs in mobiles/computers 516 (say, total count of m). The threads under a process may be similar to each other, and are represented as one example T_k under each of the two processes 702, 704. The local SEOS server 508 resolves 706 the digital information from the NFC tag, so as to ascertain the properties and data linked to the appliance e.g. 504. If it cannot locally resolve the appliance information, especially when that particular appliance is encountered for the first time by the local SEOS server 508, it queries 708 the remote server 512 in which data regarding the appliance e.g. 504 has been entered in advance. It is important to note that the NFC tags and the data (identifier) in them are generated independently from the appliances according to example embodiments, and hence any new NFC tag with a digital identifier is appliance-agnostic. The merit of this method is that any tag that is programmed to have a digital identifier do not have to have any particular appliance or appliance-category as the target to which it should be associated. The identifier gets assigned to a particular appliance typically after the NFC tag is placed on the appliance's plug and connected to the SEOS hardware 502, after which local SEOS server 508 receives the identifier. But if required, appliance manufacturers are free to assign the digital identifier to an appliance before it is connected to SEOS hardware 502. Once assigned, local SEOS server 508 stores that assignment in its local database as a digital-profile which an authorized user can modify. If authorized, the digital-profile is stored in a remote server's database too. Based on the unique identity of the appliance e.g. 504, represented by a universally unique identifier (UUID) or a unique set of characters according to preferred embodiments, the detailed information of the appliance e.g. 504 can be obtained from the databases. The local SEOS server 508 adds relevant data from the hardware to its local database and sends instruction/details 710 to the clients. For the SEOS hardware 502 client this could imply change in its internal function or following a schedule given by an optimization algorithm. For the mobile/computer 516 client this could mean updating the energy consumption and carbon footprint. The client programs in mobiles/computers 516 need not be similar in appearance or function. This advantageously opens the opportunity to various functionalities, according to

example embodiments. Under the process 704, as an example the relay-control 712 by authorized mobile/computer 516 clients is allowed. This can imply manual control by a human-user through an app, or automation using another program. Local SEOS server 508 can perform many auxiliary functions based on its local database, such as appliance location discovery (“last known location in the building” and “last time the appliance queried has been used”). A few examples are provided in the document in the Appendix.

[0060] The remote server 512 is a webserver according to some embodiments, which provides different webpages or web-services to different kind of users to use. The preliminary data to be linked to e.g. a UUID which is randomly generated is ideally decided by the manufacturer. But in absence of such a system, an authorized party who maintains the local database coupled to or incorporated at the remote server 512 can perform the linking of manufacturing details (model name, serial number, nameplate information etc.) of a known appliance, according to example embodiments. The owner or the consumer who purchased the appliance e.g. 504 can claim the appliance and link personal details to the appliance’s UUID, with options to configure privacy settings, according to example embodiments. “Claim” here implies the appliance-owner declaring to the server (either 508 or 512) that “This appliance with such UUID is mine”. That might require logging in securely on the server and entering the UUID information and attaching appliance details from certain drop-down menu. A simplistic version of how appliance details are kept by National Environment Agency (NEA) of Singapore can be seen here: <https://e-services.nea.gov.sg/els/Pages/Search/PublicSearchProduct.aspx>. Alternatively, the UUID registration can be done in a slightly easier way with an appropriate mobile app that can read the NFC tag of the appliance, noting that most smartphones these days have an in-built NFC tag-reader.

[0061] For example on configuring privacy settings, a user might be willing to associate one’s email with the appliance owned but not the phone number. In that case, when an SEOS system according to example embodiments accesses the remote server 512, only the email information is sent back for the UUID queried.

[0062] Fig. 8 shows the flowchart 800 for the remote server 512. It preferably uses multi-processing 802, 804. The threads under a process may be similar to each other, and are represented as one example T_k . Since the remote server 512 maintains a global registry for each and every appliance according to example embodiments, it has the ability to resolve 806 UUIDs

using its database. It accepts requests from authorized local SEOS servers 508s, and send back permitted details 808. Preferably under a different process 804, it accepts multiple clients – manufacturers, appliance-owners, buildings – who try to link UUIDs of appliances with appliance details, personal information or organizational information 810. For example, a university can claim ownership of a set of desktops that it purchased through its project funds for exclusive use at sockets within a laboratory. There can be various ways in which the local and the remote servers can be implemented, with the set of functionalities they offer enabled because of the intrinsic capabilities of the SEOS hardware according to example embodiments. It is worth noting that a remote server is optional for the SEOS according to example embodiments to operate. The remote server 512 is preferred for large scale and universal use of SEOS according to example embodiments, for example across multiple buildings in different countries. An organization can locally manage its own appliances and perform automated inventory management through local assignment of UUIDs in the tags of the appliances, according to example embodiments. For example, each “version 4 UUID” has 122 bits that are randomly generated, with the smallest number of UUID generation leading to repetition being approximated as $\sqrt{2^{122} \times \ln\left(\frac{1}{1-p}\right)}$, where p is the probability of repetition. To have a one in a billion chance of duplication, more than 103 trillion UUIDs have to be generated (refer e.g. to <http://www.h2database.com/html/advanced.html#uuid>). This means that two separate managers of local SEOS servers according to example embodiments can independently generate their own version 4 UUIDs for all the appliances in their own buildings and the chance of their UUIDs being duplicated is next to impossible. Examples of UUIDs are shown in Table 1.

128 bit long UUIDs, with 6 bits predetermined and 122 bits that are random																															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
7	3	e	d	b	3	9	9	1	2	f	7	4	f	9	e	8	0	4	9	c	3	c	b	9	b	e	4	5	5	3	2
4	4	2	6	e	c	6	5	0	c	4	3	4	4	2	a	b	1	9	5	a	c	6	e	8	8	f	4	b	7	7	b
1	4	c	8	2	a	5	7	a	9	d	d	4	f	0	0	a	f	5	b	e	1	2	2	f	5	6	4	e	3	c	d
8	0	9	7	d	6	3	b	9	0	b	0	4	8	1	5	a	f	b	3	9	b	2	6	1	f	5	c	e	2	f	8

Table 1. Four examples of UUIDs. The 128-bit long UUIDs are here represented using 32 hexadecimal digits. A total of 2^{122} combinations are possible, which is approximately 5.31×10^{36}

[0063] A prototype of SEOS portable-socket 900 according to an example embodiment is shown in fig. 9 at the right end, labeled "D". Fig. 9 illustrates of the physical sizes of different types of plugs: (A) An extender plug without any smartness, (B) An existing SP with local display of certain parameters but without ability to communicate, (C) A Plugwise Circle SP, and (D) An SEOS portable-socket prototype according to an example embodiment.

[0064] This illustrates that the portable-socket according to example embodiments can be of comparable size to other existing plugs despite having many components inside it. When plugs are compact, they can be pressed into adjacent wall-sockets without difficulty. A prototype of SEOS wall-socket 1000 according to an example embodiment is shown in fig. 10A. Fig. 10A shows how the appliance tag 1002 is positioned with respect to SEOS hardware 1000, with the NFC reader 1004 underneath in the body of the SEOS wall-socket 1000. In the most common scenario according to example embodiments, the NFC tag 1002 is close enough to be readable by the NFC reader 1004 only when the appliance is plugged-in. That means the physical connection is almost always certain when the NFC tag 1002 with resolvable UUID is read. Fig. 10B shows a more compact version of a SEOS wall-socket 1005 according to an example embodiment, with similar components: NFC tag 1006 on plug (here between the plug 1007 and the wall-socket 1005, NFC reader 1008 and main circuitry 1010. In the rare case of a person deliberately placing the tag near to the SEOS hardware e.g. 1000 by tilting the appliance plug, even if the SEOS ecosystem assumes the presence of appliance at first, SEOS can be pre-configured according to example embodiments to not continue operating unless the electrical behavior (such as current drawn) matches the specifications in the resolved digital-profile. Also, such an instance can easily be identified and intelligently notified to the building-operator according to example embodiments. The ecosystem of SEOS according to example embodiments would have multiple SEOS hardware managed by supervisory software, as depicted in fig. 5.

[0065] Samples of results produced by four SEOS hardware modules and corresponding server according to example embodiments are given in figs. 11A and 10B. In the samples, "Supply" shows the electrical state of the hardware as known by the local server. ON/OFF are the states that SEOS hardware modules communicate to the local server, based on the relay

status. An “offline” state is intentionally shown here indicating that a particular SEOS hardware which was reporting previously has now become unreachable due to some failure in communication. The SEOS according to example embodiments thus intelligently detects whether any SEOS hardware has gone out of reach or not. The corresponding application/program that produces such samples runs in mobile/computers 516 (refer fig. 5). Another interface is shown in fig. 12 to indicate that various visually and functionally different interfaces are possible with varying extent of appliance detail. In fig. 12, the column “*STATUS*” buttons e.g. 1200 are provided which allows a human being to control the electrical supply remotely using the app.

[0066] As seen in in fig. 11A and fig. 11B, various data can be linked to any particular “*Appliance-Name*”. Such data are obtained when the server resolves the UUID present in the appliance-tag. In fig. 11A, the SEOS-2 module shows “*Supply*” as OFF but still knows that a ‘*Dell Laptop*’ is attached to it. Also, information associated with appliances can be known, as shown in the text box 1100 for ‘*Desktop-Monitor-1*’. Such abilities according to example embodiments can advantageously help in intelligent scheduling and authorization of the appliance for smart-grid operations. In fig. 12, the ratings and other information of multiple simultaneous appliances are shown under column 1202, and the real-time measurements of voltage (column 1204), current (column 1206), active power (column 1208) and energy (column 1210) are displayed. This means the SEOS according to example embodiments already knows the expected/nominal electrical behavior of the appliance, enabling it to perform detections of any electrical anomaly based on the measurements. All this information can be time-stamped and stored in a database for further offline analytics. Apart from these, the ‘handphone’ being “HIDDEN” under first row of the column 1202 in fig. 12 denotes the possibility of adding permissions to the data that is linked to the UUID, according to example embodiments. This is analogous to setting the visibility or choosing the audience of information linked to a Facebook profile.

[0067] A sample circuit diagram of SEOS hardware 1300 according to an example embodiment (for use in e.g. portable-socket e.g. 900 or wall-sockets 1000, 1005) is illustrated in fig. 13. The diagram contains SEOS main components such as AC/DC Converter 1302 as a power supply unit, energy Integrated Circuit (IC) 1304, microcontroller and communication module 1306 with antenna, load identifier IC and antenna (i.e. NFC reader) 1308, relay 1310 for switching on/off the supply to the load, and current and voltage sensing 1312 and 1314.

Although this diagram illustrates a sample circuitry of a single-gang socket prototype as shown in fig. 10B, additional components like the Energy IC and Identifier IC can be added in a similar way for e.g. a double gang socket. The AC/DC converter 1302 converts AC electrical supply in the building to low voltage DC supply to be used by the electronic circuit. The energy IC 1304 gathers real-time current and voltage data from sensing parts 1312 and 1314. Then it computes values of real power, reactive power, apparent power, corresponding energy values, power factor, frequency, IC's temperature, current/voltage waveforms in such a way that they are digitally available to the microcontroller module 1306. The identifier in a near-field tag is accessible through identifier IC and its antenna 1308 operating around 13.56 MHz in this example embodiment. The identifier IC makes identifier information digitally available to the microcontroller and communication module 1306, which is then used by the microcontroller and communication module 1306 and its antenna operating at e.g. Wi-Fi frequency to communicate to SEOS local server. Based on the intelligence provided by SEOS local server (compare fig. 12), the microcontroller and communication module 1306 contextually measures parameters provided by the energy IC 1304. They are then matched against the ad-hoc operating criteria to ensure safe operation of the plug-load connected through actuation of the relay 1310.

[0068] An example of the new functionality of customized electrical protection of plug-loads that example embodiments of the present invention can achieve is shown as a sequence diagram 1400 in fig. 14. The exchange of voltage and current limits transfer based on digital-profile could include the power-quality requirements of the plug-loads connected. For example, if a sensitive plug-load should not be supplied a voltage above 240V, SEOS hardware 1402 according to an example embodiment acquires this information from the SEOS local server 1404 and reports of any over-voltage violations experienced by the plug-load. The resolved digital-profile from the identifier determines the contextual electrical parameter to be measured and processed locally at the SEOS hardware 1402. The digital-profile may have different criticality for different appliances even if they belong to the same appliance category. For example, a television from X-manufacturer and a television from Y-manufacturer could have different electrical limits in their digital-profiles. Even ownership and power-rating of an appliance could be conditions to determine criticality of electrical violations. For example, monitors/screens associated with security cameras in a building could be specifically reported for unusual variations in power drawn. Ideally, such monitors must be not dim or switch off.

This new functionality enables SEOS mechanism according to example embodiments to intelligently tackle a wide variety of electrical scenarios involving over-currents, under-currents, over-voltages and under-voltages in a context-specific manner. Additionally, this helps to evaluate quality of the electrical power supplied to each of the electrical appliances. The local SEOS server 1404 can instruct the SEOS hardware 1402 to measure voltages at different rates so as to determine power-quality problems such as voltage-flicker.

[0069] An example of physical placement of SEOS hardware modules according to example embodiments within a building-grid 1410, i.e. electrical network within a generic building, is shown in fig. 14B. A multi-floor or multi-level building typically receives incoming electrical supply at the main distribution board/panel 1412, and distributes it further to different levels through the corresponding distribution boards e.g. 1414 at each level. The electricity is further distributed to various loads e.g. plug-load 1418 at the terminals of the electrical network. SEOS hardware modules e.g. 1416 act as the mechanism of supplying electrical power to any plug-load e.g. 1418 that can be connected to the building-grid.

[0070] An example of communication network corresponding to fig. 14B is shown in fig. 14C. In a building 1420, when a plug having a tag with the identifier e.g. 1422 is plugged into a SEOS module according to an example embodiment, the SEOS firmware or embedded code 1424 obtains the identifier and the contextual plug-load measurements and then uses the local communication network infrastructure 1426 to send that information to a SEOS local-server 1428 according to an example embodiment. This enables the local-server 1428 to provide digital services to dedicated interfaces e.g. 1430 associated with a building management system or building operating system, and also provide information and control through mobile interfaces e.g. 1432. For making this scalable for multiple buildings and to add more digital services, a cloud server or remote server 1434 according to an example embodiment is linked through the internet to the local communication infrastructure.

[0071] A Smart Electrical Outlet/ Socket (SEOS) according to example embodiments can uniquely identify appliances, associate digital-profiles of that appliance and also can perform electrical measurements to determine various electrical measurements such as voltage, current, power, energy, and also the power-quality. The features of the SEOS according to example embodiments, and the synergy of those features, have given rise to new results and functionalities over existing smart plug technology. For example, having comprehensive digital-profiles for the appliances (refer e.g. figs. 11A, 11B and 12) and/or a Building Firewall

as described herein are some of the advantageous parts of the SEOS ecosystem according to example embodiments. Numerous commercial applications and digitalized building services are possible because of embodiments of the present invention. Intuitive and use-friendly interfaces, platforms and a fully-fledged SEOS management system according to different embodiments can further enhance embodiments described herein.

[0072] The advantages of the SEOS according to example embodiments over existing smart-plugs can include:

- identifying tagged electrical appliances uniquely unlike any other commercial SP
- making reporting and tracking the physical location of the appliance possible, which isn't possible with existing SPs

- detecting and analyzing power-quality experienced at the socket by the appliances. This aspect is becoming more important with increasing renewable energy penetration.

- Wall-socket version meaningfully allowing rule-based authorization or prohibition of operation of electrical appliances in a building, with awareness regarding the exact appliance connected. This adds a smart security feature to buildings. When the manufacturer does the tagging of appliances, it advantageously makes automated checking of genuineness of the appliance feasible.

- logging the history of any appliance and perform scheduling based on the appliance-specific information. This aids in an appliance-aware demand response management and reduces human errors. It also allows computation of appliances' value depreciation as per its actual utilization. Under-utilization or over-utilization (if any) of purchased appliances can be easily identified by an organization.

- enabling automated inventory management, and even online inventory listing. In a large building, all the SEOS hardware with corresponding appliances connected to them can be tabulated. The appliance doesn't have to be electrically ON. Only the proximity of the appliance's tag to SEOS is required.

- avoiding the requirement of manually assigning appliances to SPs like most SPs would require since the identification is automated. This is especially useful when the sockets to be managed are numerous, as found in large buildings.

- not requiring reconfiguration in the case where appliances get shifted from one outlet to another. This is important in a building where appliances are used in an ad-hoc manner, probably due to changing occupants.

- by accessing the electrical rating of the appliance identified, maintaining more complex and intelligent rules towards socket behavior (referred as *Building Firewall*). For example, the protection of the socket through a rule based on current threshold can be done by many existing SPs. But SEOS can intelligently maintain different thresholds for differently rated devices.

[0073] Embodiments of the present invention can have one or more of the features and associated benefits/advantages in table 2.

Feature	Benefit/Advantage
Identification of billions of electrical appliances or plug-loads when they are connected to the SEOS hardware	The plug-loads can be tracked in terms of location, history, performance, ownership and many other details which together form <i>digital-profiles</i> of the loads. It also helps to authenticate appliance operation based on simple or complex software rules. This feature is named as <i>Building Firewall</i> , and it adds a new kind of security to the building.
Real-time knowledge of electrical measurements and power-quality estimations without the need for complex and expensive power-analyzers	For future grids with high renewable energy penetration resulting in increased uncertainty and variability of electrical supply, buildings will be able to do automated power-quality event detection, their isolation, and also perform well-informed remedial actions. Appliance-specific over-current, under-current, over-voltage, under-voltage scenarios can also be detected to provide software-based customized electrical protection to any appliance identified.
Context-aware control and scheduling of plug-loads	As a synergistic result of identifications which influence measurements and subsequent computations, the SEOS can benefit smart-grid operations (such as appliance scheduling) with unprecedented

	context-awareness within a building, among many buildings, and even among districts. This serves the broader objective of sustainability.
Automated generation of real-time inventory list of appliances	New digitalized business opportunities that can result in realistic and fast automated market research, and value generation for appliance manufacturers.

Table 2

[0074] SEOS hardware according to example embodiments can be a gateway technology with many possible applications. It can digitalize the appliance management and operation, thereby contributing to better energy management resulting in greener use of energy. A few non-limiting example applications are as follows:

- Automated Inventory management of appliances. The assets under an organization can be tracked when connected to SEOS ecosystem according to example embodiments and the consumption patterns can be monitored. Accurate location discovery of registered appliances, by the authorized personnel, such as “last connected location” is also possible. This saves time and human effort.

- Digital authorization of appliances thereby improving electrical safety and also security in general. The appliances can be authorized based its electrical ratings, electrical operation, and also based on the user credentials or any other information linked to the appliance. This concept is named here as Building Firewall, where the electrical connections of the building’s electrical network with the appliances could be made rule-based, providing a new kind of security this way.

- With penetration of intermittent renewables like solar energy increases in their share, uncertainty and variability of power also increases. For future buildings, automatic power-quality monitoring and reporting is necessary. This would help isolate problems and take well-informed remedial decisions.

- Intelligent scheduling of appliances based on the real-time appliance behavior and appliances’ digital-profile is possible, thus making SEOS according to example embodiments suitable for any dynamic environment with many appliance changes happening in parallel. This would help in practical demand response management for smart-grids. Many studies emphasize

that significant economic savings are possible through demand response. This is especially important for a scenario where electricity prices go up with time. SEOS according to example embodiments would help establish within buildings a truly intelligent Enernet (energy internet) capable of making economic savings and reducing carbon-footprints. SEOS according to example embodiments is a green technology in this respect.

- Digital statistics on the use of different appliances within any building with SEOS according to example embodiments installed can provide insight into consumption patterns on different brands of appliances used. This will take digitalization into another level, allowing product differentiation. For example, questions such as these can be answered in real-time – “How many appliances currently used in the building have Singapore National Environment Agency’s energy efficiency rating of ‘Very Good’? How many of them belong to a certain manufacturer/brand?” Several data analytics and data mining can be performed to generate new insights and to make strategic decisions.

- Providing any user of the building the service to track location, energy consumption, CO₂e impact etc. of their own devices is possible. This feedback could be made to positively affect the behavior or psychology of the end users. The cumulative usage could be used to know the carbon impact of the buildings over a large period of time.

[0075] The above commercial applications and building services have to be seen in the context of Smart Nation initiatives, digital transformations, smart-grid evolutions, liberalization of electricity market, expansion of contestability for electricity consumers, and implementation of full retail competition by Energy Market Authority of Singapore. SEOS according to example embodiments is aligned with governmental efforts, and it is useful for building managers and also the occupants. It can be readily integrated with cloud-computing and edge-computing mechanisms, or a hybrid of them.

[0076] A comparison of SEOS wall-socket and portable-socket with existing solutions are given in Table 3.

Features	Conventional Socket	Most Commercial Smart Plugs	SEOS Wall-Socket	SEOS Portable-Socket
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Electrical connectivity to the appliance and fuse-based protection	✓	✓	✓	✓
Physical security (not easily displaceable)	✓	✗	✓	✗
Remote ON/OFF Control of the socket	✗	✓	✓	✓
Measurement of Energy Consumption	✗	✓	✓	✓
Real-time voltage, current, active & reactive powers	✗	●	✓	✓
Recording/display of electrical measurements and analysis	✗	●	✓	✓
Monitoring of power-quality information and anomalies	✗	✗	✓	✓
Automated identification & locating of appliances	✗	✗	✓	✓
Automated appliance authentication (Building Firewall)	✗	✗	✓	✓
Customized over-current, under-current, over-voltage, under-voltage reporting and protection	✗	✗	✓	✓

Automated, real-time and online appliance list	✕	✕	✓	✓
Act as infrastructure for smart-grid applications (scheduling, optimization, accurate item-wise billing, auditing)	✕	✕	✓	●
✓ - Capable ✕ - Out of scope ● - Optional				

Table 3. Comparison of commercially available electrical sockets and smart plugs with SEOS hardware according to example embodiments.

[0077] Embodiments of the present invention can digitalize the appliance management and operation, thereby contributing to better energy management resulting in greener use of energy. A few applications of example embodiments are as described next in more detail, by way of example, not limitation.

[0078] Automated Asset Management of Plug-loads

[0079] The electrical plug-load assets under an organization can be tracked and the consumption patterns can be monitored. Accurate location discovery of registered appliances, by the authorized personnel, such as “last seen location” and “last seen time” is also possible. This saves time and human effort. SEOS according to example embodiments can also provide information on under-utilization of assets (appliances) purchased in offices, since its can track appliances even when they are not turned ‘on’. This would also help in automated energy-auditing. Additionally, finding out asset depreciation and remaining useful life of appliances based on the extent of actual consumption, rather than the date of purchase, becomes viable.

[0080] Building Firewall for Digital Authorization

[0081] Embodiments of the present invention provide the option of allowing electrical supply to an appliance only if it meets predefined criteria. The appliances can be authorized based on electrical ratings, electrical operation, compliance certificates, and also based on the user credentials (i.e. access management) or any other information linked to the appliance. This

provides electrical safety and also security in general, and even prevents unintentional violations of safety standards such as those set by Standards, Productivity and Innovation Board (SPRING), Singapore. The building firewall, similar to a firewall in computer operating systems, enables an administrator to use rules to define socket-behavior, such as allowing/prohibiting certain appliances. This can provide a new kind of security which is cyber-physical in nature. The complexity and the intelligence of a rule imposed depend on the building manager and the desired outcome. For example, a rule could be set that “no big printers in an office will be supplied electricity if the number of desktop monitors that are ‘on’ are below a certain number”. In large offices, this rule could help allocate their resources proportionate to the employees to be catered to.

[0082] Power and Power-Quality Monitoring

[0083] With penetration of intermittent renewables like solar energy and the increase in their share, uncertainty and variability of power also increases. For future buildings, automatic power-quality monitoring and reporting is deemed necessary. SEOS according to example embodiments can inform regarding nominal harmonic currents expected from an appliance, and through its metering IC it can directly determine voltage sags and disturbances as experienced by the appliances. It could happen that individually the electrical devices pose no power-quality issue. But collectively when they draw nonlinear currents, a large part of the electrical network could get affected. SEOS according to example embodiments not only detects certain power-quality events, but also holds the information as to the list of appliances connected to the building-grid during the respective power-quality events. The monitoring by SEOS according to example embodiments would help isolate problems and take well-informed remedial decisions.

[0084] Appliance Scheduling, Optimizations, and On-demand Operations

[0085] Intelligent and optimized scheduling of appliances based on the real-time appliance behavior and appliances’ digital-profile is possible, thus making SEOS according to example embodiment suitable for any dynamic environment with many appliance changes happening in parallel. This would help in practical demand side management for smart-grids. Many studies emphasize that significant economic savings are possible through demand side management. This is especially important for a scenario where electricity prices go up with time. SEOS according to example embodiments would help establish a truly intelligent Enernet (energy internet) capable of making economic savings and reducing carbon-footprints. Demand-

response operations, such as switching off non-critical loads for helping the main grid supplying electricity to stabilize, are also possible. For example, refrigerators of an area could be switched off for a short time when the power grid is stressed because of high electricity demand, thus stabilizing the grid without having to turn on more thermal generators to mitigate the stress.

[0086] Real-time Statistics

[0087] Digital statistics on the use of different appliances within any building with SEOS according to example embodiments installed can provide insight into consumption patterns on different brands of appliances used. This will take digitalization into another level, allowing real-time market research rather than survey-based approximated market research. For example, questions such as these can be answered in real-time – “How many appliances currently used in the building have NEA’s energy efficiency rating of ‘Very Good’? How many of them belong to a certain manufacturer/brand?” Several data analytics and data mining can be performed to generate new insights and to make strategic decisions. Preferably, embodiments of the present invention are able to anonymize the data provided, as and when required.

[0088] New Digitalized Services

[0089] The benefits of SEOS according to example embodiments include value gained through disaggregated appliance data. This can help perform appliance-itemized billing and also personalized billing for the users of a building-grid, especially in large commercial buildings. Providing any user of the building the service to track location, energy consumption, CO₂e impact etc. of their own electrical appliances is possible. These feedbacks on energy and carbon footprint could be designed to positively affect the behavior or psychology of the end users. Also, the cumulative data could be used to know the realistic carbon impact of the buildings over a large period of time.

[0090] New commands by a building-user that become possible with the inception of SEOS according to example embodiments include:

[0091] — List the exact locations of all the plug-loads owned by me,

[0092] — List the energy consumption statistics and graphs of my appliance-Y,

[0093] — Opt-in/opt-out appliance-Y with regards to automated load-shifting,

[0094] — Report my appliance-Y as missing,

[0095] — Request BOS to reserve socket-a for my appliance-Y for an interval-T, and

[0096] — Display and rank the energy efficiencies and carbon footprint of my appliances within my workplace.

[0097] New commands by a building-operator to BOS that become possible with the inception of SEOS according to example embodiments include:

[0098] — List the exact locations of all the plug-loads under my organization-K,

[0099] — List the plug-loads connected to the building now/last day/last week/this month/...,

[0100] — List the energy consumption statistics and usage pattern of asset-X and its similar assets,

[0101] — List the owner of appliance-Y (if owner has registered, and has been set to 'visible'),

[0102] — Locate asset-X along with its "last seen" status; check if it is idle,

[0103] — Auto-report anomalous behavior of any plug-loads at sockets-a,b,c,....,

[0104] — Authorize/unauthorize appliance-Y for socket-a,b,c,....

[0105] The above benefits and building services can e.g. be seen in the context of ongoing digital transformations, smart-grid evolutions, liberalization of electricity market, expansion of contestability for electricity consumers, and implementation of full retail competition. SEOS according to example embodiment is useful for occupants, building operators and also for any entity which requires a building-grid to be responsive. Using a processing and communication module such as Particle Photon or ESP8266 in example embodiments can provide the pragmatic advantage of secure over-the-air programming. This implies that new program codes can be securely and wirelessly added to the processing units of all the SEOS hardware units according to example embodiment in a building, thereby enhancing the extent of edge-computing performed. The option to update SEOS according to example embodiment with least physical effort, so as to improve its functions, would also prevent unwanted obsolescence. Hence, the objective of higher sustainability through minimizing electronic waste can additionally be considered in SEOS according to example embodiments.

[0106] Figure 15 shows a schematic drawing illustrating an electrical outlet/socket device 1500 according to an example embodiment. The electrical outlet/socket device 1500 comprises a sensor 1502 for detecting the presence of an identification tag associable with an electrical appliance, the sensor 1502 being configured for extracting a unique identifier of the electrical appliance stored in the identification tag; one or more electrical conductors e.g. 1504

configured for coupling to the electrical appliance for supply of power to the electrical appliance; a measurement unit 1506 coupled to the one or more electrical conductors e.g. 1504 for performing electrical measurements; and a processor 1508 configured for associating the electrical measurements with the unique identifier for further processing.

[00107] The unique identifier may be resolvable into a digital profile of the electrical appliance.

[00108] The sensor 1502 may be based on near-field communication.

[00109] The electrical outlet/socket device 1500 may further comprise a communication unit 1510 for data communication with a computing device. The processor 1508 may be configured for communicating data representing the unique identifier and the associated electrical measurements to the computing device via the communication unit 1510.

[00110] The electrical outlet/socket device 1500 may further comprise a power switch/relay 1512 configured for selectively enabling the power supply to the electrical appliance. The power switch/relay 1512 may be configured for control based on an external control signal received by the electrical outlet/socket device 1500 and/or based on an internal control signal. The power switch/relay 1512 may be configured for selectively enabling the power supply to the electrical appliance based on the unique identifier of the electrical appliance, wherein the power switch/relay 1512 may be configured for selectively enabling the power supply to the electrical appliance based on a digital profile resolved from the unique identifier of the electrical appliance.

[00111] The unique identifier may comprise a randomly generated universal unique identifier, UUID.

[00112] The electrical outlet/socket device 1500 may be in the form of a wall socket or a portable socket/plug.

[00113] Figure 16 shows a schematic drawing illustrating a system 1600 for smart electrical power supply within a building, according to an example embodiment. The system 1600 comprises an electrical outlet/socket device 1602, for example in the form of the electrical outlet/socket device 1500 shown in Figure 15; and a computing device 1604 configured for data communication with the electrical outlet/socket device 1602; wherein the computing device 1604 is configured for processing data representing the unique identifier and the associated electrical measurements.

[00114] The computing device 1604 may be further configured for generating control signals for the electrical outlet/socket device 1602 based on the processing of the data.

[00115] The system 1600 may further comprise a user interface 1606 for displaying of information based on the processed data and/or for user input of data for association with the unique identifier of the electrical appliance.

[00116] The system 1600 may further comprise a remote server 1608 configured for data communication with the computing device 1604 and with other systems for smart electrical power supply.

[00117] The computing device 1604 may comprise a local server for the building.

[00118] The system 1600 may be configured for implementing one or more of a group consisting of fuse-based protection, energy consumption measurement, real-time voltage measurement, real-time current measurement, real-time active power measurement, real-time reactive power measurement, recording of the electrical measurements, displaying of the electrical measurements, power-quality information monitoring, power-quality anomalies monitoring, automated identification of appliances, automated locating of appliances, automated appliance authentication, automated appliance list generation, scheduling applications, optimization applications, billing applications, and auditing applications.

[00119] In one embodiment, illustrated in the flowchart 1700 shown in Figure 17, a method for smart electrical power supply within a building is provided, the method being performed using an electrical outlet/socket device, and the method comprising, at step 1702, detecting the presence of an identification tag associable with an electrical appliance, and extracting a unique identifier of the electrical appliance stored in the identification tag; at step 1704, performing electrical measurements; and at step 1706 associating the electrical measurements with the unique identifier for further processing.

[00120] The unique identifier may be resolvable into a digital profile of the electrical appliance.

[00121] The detecting step 1702 may be based on near-field communication.

[00122] The method may further comprise data communication between the electrical outlet/socket device and a computing device.

[00123] The method may comprise communicating data representing the unique identifier and the associated electrical measurements to the computing device.

[00124] The method may further comprise selectively enabling the power supply to the electrical appliance. The method may comprise control of the power supply based on an external control signal received by the electrical outlet/socket device and/or based on an internal control signal. The method may comprise selectively enabling the power supply to the electrical appliance based on the unique identifier of the electrical appliance, wherein the selectively enabling the power supply to the electrical appliance may be based on a digital profile resolved from the unique identifier of the electrical appliance.

[00125] The unique identifier may comprise a randomly generated universal unique identifier, UUID.

[00126] The electrical outlet/socket device may be in the form of a wall socket or a portable socket/plug.

[00127] The method may comprise processing data representing the unique identifier and the associated electrical measurements using a computing device. The method may further comprise displaying of information using a user interface based on the processed data using a user interface and/or user input of data for association with the unique identifier of the electrical appliance using the user interface.

[00128] The method may comprise using a computing device and/or a remote server for the further processing. The method may further comprise using the remote server for communication with other systems for smart electrical power supply. The computing device may comprise a local server for the building.

[00129] The method may be performed for implementing one or more of a group consisting of fuse-based protection, energy consumption measurement, real-time voltage measurement, real-time current measurement, real-time active power measurement, real-time reactive power measurement, recording of the electrical measurements, displaying of the electrical measurements, power-quality information monitoring, power-quality anomalies monitoring, automated identification of appliances, automated locating of appliances, automated appliance authentication, automated appliance list generation, scheduling applications, optimization applications, billing applications, and auditing applications.

[00130] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

Also, the invention includes any combination of features, in particular any combination of features in the patent claims, even if the feature or combination of features is not explicitly specified in the patent claims or the present embodiments.

[00131] For example, interfacing website for manufacturers and end users to register their appliances can be developed and provided for different embodiments. The mobile and desktop interfaces for demonstrating the function of SEOS according to example embodiments described herein can be improved. A fully-fledged platform with applications, e.g. meant for the buildings, being showcased in a similar fashion as a modern app-store may be provided in different embodiments.

CLAIMS

1. An electrical outlet/socket device comprising:
 - a sensor for detecting the presence of an identification tag associable with an electrical appliance, the sensor being configured for extracting a unique identifier of the electrical appliance stored in the identification tag;
 - one or more electrical conductors configured for coupling to the electrical appliance for supply of power to the electrical appliance;
 - a power switch/relay configured for selectively enabling the power supply to the electrical appliance;
 - a measurement unit coupled to the one or more electrical conductors for performing electrical measurements including measuring power-quality experienced at the electrical outlet/socket device by the electrical appliance;
 - a processor configured for associating the electrical measurements with the unique identifier for further processing; and
 - a communication unit for data communication with a computing device to communicate data representing the unique identifier and associated electrical measurements to the computing device and to receive a command and associated matching criteria including a power-quality requirement from the computing device;wherein the processor is configured for contextually measuring the power-quality experienced at the electrical outlet/socket device by the electrical appliance to determine electrical parameters based on the command received from the computing device, matching the electrical parameters against the associated matching criteria, and actuating the power switch/relay based on the matching.
2. The electrical outlet/socket device of claim 1, wherein the unique identifier is resolvable into a digital profile of the electrical appliance.
3. The electrical outlet/socket device of claims 1 or 2, wherein the sensor is based on near-field communication.
4. The electrical outlet/socket device of any one of the preceding claims, wherein the communication unit is configured for wireless data communication with the computing device.

5. The electrical outlet/socket device of any one of the preceding claims, wherein the power switch/relay is configured for control based on the command received by the electrical outlet/socket device and/or based on an internal control signal.
6. The electrical outlet/socket device of any one of the preceding claims, wherein the unique identifier comprises a randomly generated universal unique identifier, UUID.
7. The electrical outlet/socket device of any one of the preceding claims, in the form of a wall socket or a portable socket/plug.
8. A system for smart electrical power supply within a building, comprising:
an electrical outlet/socket device of any one of the preceding claims; and
the computing device configured for data communication with the electrical outlet/socket device;
wherein the computing device is configured for processing data representing the unique identifier and the associated electrical measurements.
9. The system of claim 8, wherein the computing device is further configured for generating the command for the electrical outlet/socket device based on the processing of the data.
10. The system of claims 8 or 9, further comprising a user interface for displaying of information based on the processed data and/or for user input of data for association with the unique identifier of the electrical appliance.
11. The system of any one of claim 8 to 10, wherein the computing device comprises a local server for the building and/or a remote server.
12. The system of claim 11, wherein the remote server is configured for data communication with other systems for smart electrical power supply.

13. The system of any one of claims 8 to 12, configured for implementing one or more of a group consisting of relay-based protection, energy consumption measurement, real-time voltage measurement, real-time current measurement, real-time active power measurement, real-time reactive power measurement, recording of the electrical measurements, displaying of the electrical measurements, power-quality information monitoring, power-quality anomalies monitoring, automated identification of appliances, automated locating of appliances, automated appliance authentication, automated appliance list generation, scheduling applications, optimization applications, billing applications, and auditing applications.

14. A method for smart electrical power supply within a building, the method being performed using an electrical outlet/socket device, and the method comprising:

- detecting the presence of an identification tag associable with an electrical appliance, and extracting a unique identifier of the electrical appliance stored in the identification tag;

- performing electrical measurements including measuring power-quality experienced at the electrical outlet/socket device by the electrical appliance;

- associating the electrical measurements with the unique identifier for further processing;

- performing data communication with a computing device to communicate data representing the unique identifier and associated electrical measurements to the computing device and to receive a command and associated matching criteria including a power-quality requirement from the computing device at the electrical outlet/socket device; and

- using the electrical outlet/socket device to contextually measure the power-quality experienced at the electrical outlet/socket device by the electrical appliance to determine electrical parameters using the electrical outlet/socket device based on the command received from the computing device, matching the parameters against the criteria, and actuating a relay based on the matching.

15. The method of claim 14, wherein the unique identifier is resolvable into a digital profile of the electrical appliance.

16. The method of claims 14 or 15, wherein the detecting is based on near-field communication.

17. The method of any one of claims 14 to 16, wherein the data communication between the electrical outlet/socket device and the computing device is performed wirelessly.
18. The method of claim any one of claims 14 to 17, comprising control of the power supply based on the command received by the electrical outlet/socket device and/or based on an internal control signal.
19. The method of any one of claims 14 to 18, wherein the command is based on a digital profile resolved from the unique identifier of the electrical appliance.
20. The method of any one of claims 14 to 19, wherein the unique identifier comprises a randomly generated universal unique identifier, UUID.
21. The method of any one of claims 14 to 20, wherein the electrical outlet/socket device is in the form of a wall socket or a portable socket/plug.
22. The method of any one of claims 14 to 21, comprising processing data representing the unique identifier and the associated electrical measurements using the computing device.
23. The method of claim 22, further comprising displaying of information using a user interface based on the processed data using a user interface and/or user input of data for association with the unique identifier of the electrical appliance using the user interface.
24. The method of any one of claims 14 to 23, wherein the computing device comprises a local server and/or a remote server for the further processing.
25. The method of claim 24, further comprising using the remote server for communication with other systems for smart electrical power supply.
26. The method of claims 24 or 25, wherein the local server is for the building.

27. The method of any one of claims 14 to 26, performed for implementing one or more of a group consisting of relay-based protection, energy consumption measurement, real-time voltage measurement, real-time current measurement, real-time active power measurement, real-time reactive power measurement, recording of the electrical measurements, displaying of the electrical measurements, power-quality information monitoring, power-quality anomalies monitoring, automated identification of appliances, automated locating of appliances, automated appliance authentication, automated appliance list generation, scheduling applications, optimization applications, billing applications, and auditing applications.