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(54) Energy Management and Building Automation System

Summary

Energy management and building automation systems including local networks or home automation data buses. Each load to be controlled is connected to the bus via the control module. The first microcomputer preferably lies outside the customer building adjacent to the power company meter. The second microcomputer is preferably placed inside the customer building. The two microcomputers can communicate with each other and with various load control modules. The first microcomputer communicates with the power company via a suitable communication link. The second microcomputer serves in part as an input/output terminal for the system, allowing the customer to set parameters and ask the system questions about power usage information. This displays the report requested by the customer, and also displays messages transmitted by the power company and any one microcomputer. The first microcomputer acts as a master controller and/or a network server to communicate with the world located outside the building, communicate with the operator of the main data collector and local control network, and communicate with the second microcomputer providing a backup function.

Drawings Accompanying the Abstract

Drawing 1

Statement

[Technical Field]

The present invention relates to home or business automation applications and power distribution system management. In particular, the present invention relates to a computer control system for demand side management of or for controlling electrical loads in residential or commercial buildings. The system preferably utilizes power line carrier (PLC) technology for communication between the control computer and the load in the building and PLC or RF technology for communication with local power meters (i.e., the customer) of facilities provided by the utilization company. This may utilize PLC technology or other communication technology for communication between the user company and the customer building. Additionally, the present invention relates to the use of a system for providing bridges between external data communication services, devices, entertainment services and communication devices within a customer building (e.g., a home).

[Background Technology]

For years, there has been much interest in achieving more efficient use of power generation capabilities and more sophisticated control of electrical loads by users. As ecological shocks and increased awareness of economic costs due to insufficient use of resources have arisen, power customers wish to change their usage patterns. Some power companies already offer speeds that change over time during the day (rate) to encourage customers to operate devices such as clothes dryers, pull pumps, and dishwashing machines during non-peak times. In general, high speed is imposed during a certain time period of peak demand and low speed is applied during other time periods other than peak demand. An alternative approach may be to extend the daytime rate setting to allow the rate to change more frequently (e.g., by hours). In this way, it will be necessary for the customer to know each speed change before deciding at which speed to operate the device. In order to automate this approach, the power customer must be able to monitor and control their use through more valid loads in the customer's residential or commercial location.

However, customers typically only know the benefits of using a time management device when reviewing monthly invoices that provide poor information. The customer does not know exactly how much it costs to operate one device compared to another device under actual usage conditions. Using monthly invoice details to compare these costs is most likely impractical because it is impossible to have a long control experience of several months, with the exception of one month of use of a first device and another month of use of a second device, where all other energy consumption is constant. Without this type of control experience, information cannot be obtained from bills about the cost of operating a particular device, the comparative cost of operating two different devices, or how much more costs may be saved by operating a given device at a certain speed. Therefore, There is a need for a system that provides the customer with reports on the amount of power consumed and the cost of operating these devices using one or more devices in hours.

It is also necessary to allow the customer to make cost-based decisions regarding the operation of the device so that these decisions can be implemented. For example, a customer may be able to operate the pool heater as long as the energy cost is below the amount set by the customer (i.e., predetermined) or as long as the outside temperature is within a predetermined range. As another example, a customer who does not know that a new, more efficient device consumes much less energy because the power consumption by an aging existing device is unknown may be late in their decision to replace an aging device. Commercial customers will be able to make process selection decisions based on the cost of comparative energy if these costs can be presented.

Because the speeds imposed on electrical energy are at least part of the function of the system-wide demand (e.g., as reflected in the fuel cost), a customer with a fixed budget may use power more when the speed is lower than what can be done at higher speeds. Therefore, such customers will want to be able to make speed-dependent usage decisions. Of course, if the speed can be changed at any time by the user company, the customer will not see or be interested in the broadcast of the speed information. An automatic response broadcast to speed would be desirable. Such an automatic response can take many forms and will be considered not only for the newly announced speed, but also for other factors such as sensing temperature, time of day, or emergency task (e.g., device priority level). The inability to respond automatically may be one factor that hinders the development of flexible speed-change broadcasts, and existing speed-change broadcasts are generally limited to communicating the beginning and end of peak and off-peak speed cycles.

Allowing customers to control their usage patterns so that utilization decisions can be made is only covered as an aspect of power management. Often, customers' voluntary behavior is not enough to avoid problems such as excessive power demand. Ideally, the load management system should allow the user as well as the power provider (i.e., the utilization company) to control at least some degree of the loads connected to the main power.

These lead to the realization of a variety of systems that allow control functions such as load shedding (i.e., selective turning off of devices, or loads) to be performed. For example, there are a number of home and building automated systems that can be obtained commercially and from literature. Many of these automatic systems allow users to schedule devices to turn on, or operate, at a limited time. Some will prevent certain devices from operating during published high-speed or high-demand periods. If there are, there may be very few that allow the power supplier to selectively move loads out of the system (e.g., to a specific customer's purpose-specific load) or to turn them on only for a set amount of time. A significant problem arises for electric utility companies when excessive loads may arise from abnormal power or extreme weather conditions (e.g., heat waves or abnormal freezing), which may be caused by natural phenomena such as storms. Instantaneous power is restored or many disconnected loads are created on the line, and in some cases, all the loads connected to the power distribution grid or the energization of the connected loads again generates a huge surge current, which is the load. It can cause large transient voltage spikes due to line and transformer inductance, destabilize power distribution networks and damage equipment connected to the main power supply. A safety feature can switch the substation and generator off-line so that the equipment is not damaged at the very moment the substation and generator need to be brought on-line to meet load demand. In case of a power emergency, reasonable electricity utilization companies prevent damage by broadcasting requests to radio stations that customers turn off equipment and other loads until power is restored. If the utilization company can control and change the restoration of power to loads within its service area from a central location, the threat of such a transient state or the problems for dealing with them can be significantly reduced. The utilization company or government agency will be able to selectively distribute power to any type of load and withdraw power from any form of load during the problematic situation. For example, during peak load times such as natural disasters and excessively hot summer days, there may be an active power system management plan to allocate power distribution to specific customers or specific devices such as water heaters, pool pumps,

air conditioners, or generally low priority (i.e., non-critical) loads to protect the generator or distribution system. By adopting this method, the facility company can eliminate only the cost of substation installation or production capacity to withstand such extreme situations.

Other service providers (e.g., waterworks, gas providers, and cable television companies) wish to talk to their customers, but so far the system for doing so is limited and has a limited value in terms of the cost of installing a communication network and flexible control system for distribution.

From the above, it is clear that there is a need for an automation system to monitor energy (electricity) consumed by a particular load operated by a customer as well as by a residential or commercial installation customer as a whole. There is a greater need for an automation system that is easily operated by the facility customer to allow the customer to control the operation of such rods. Preferably, the system causes the customer to program the rod so that it functions or does not function in response to the energy speed information supplied by the power company and the parameters provided by the customer. Further, there is a need for a system that allows the power company to selectively control this type of rod.

[Summary of Inventions]

Such an automation system according to the invention includes a localized network that is well-based on a home automation data bus such as CEBus of the Electronic Industry Association, for which parts are sold by Intelon Corporation of Ocala, Florida (USA). Each load to be controlled by the automation system is connected to the bus via the control module. The control module may comprise a relay or switch (hereafter, a breaker or circuit breaker) to isolate the rod from the main power, depending on the command or in the event of a power failure, or in any case. In addition, the control module may be comprised of a current monitor to determine if the connected rod is a drawing current, or a power monitor to monitor the power consumed by the rod (energy consumption can be calculated). The power monitor may place data regarding the power consumed by the rod on the bus in response to the query message. The two types of monitors may place a message on the bus to indicate the load state or a change in the load state. Other forms of rod control modules may include dimmer circuits (for modules used as lamps) or speed control circuits (for modules used as motors). Thus, various forms of control modules may be considered. The system also preferably includes a pair of microcomputers. The first microcomputer is preferably disposed outside the customer's building adjacent (or even within the housing thereof) to the electrical installation power meter. The second microcomputer is preferably placed inside the client's building. The two microcomputers are mounted to communicate with each other and to communicate with various load control modules via a network/data bus (e.g., using a CEBus transceiver implementing a CEBus prototype); additionally, at least the first microcomputer is preferably mounted to communicate with the facility company via certain suitable communication links (e.g., by using a power line carrier system, radio, telephone, optical fiber, or cable television network). Preferably, the electrical installation meter is in a form that can be read remotely; for this purpose, the electrical installation meter is preferably provided with a CEBus interface unit comprising a bus transceiver so that the electrical installation meter can be read using a command transmitted via the bus. Thus, the watt-time meter of the facility is preferably readable by at least one microcomputer via a network/data bus. Implementations of the CEBus protocol may be utilized, including power-line carrier versions, RF versions, or infrared transmission versions. CEBus power-wire carrier technology is preferred. A network of a different design from the CEBus may also be used, with suitable modifications; One example is Echlon's LONWOTKS. If the network/data bus is a CEBus system or other power-wire carrier technology, all data communication within the customer's building occurs via an AC power line. This means that the system can be installed in a pre-existing, already wired building without the need to install special or extra wiring. However, the design of the system is flexible enough to allow the switch to be disconnected from the rod in a new configuration; and as the two demands are not continuous, the switching circuit may operate at the thermovoltage current for improved stability and cost reduction. In other words, certain circuits that may impart a legitimate signal on the main power may execute the operation of the appliance, since the appliance may be turned on and off via breakers in their control modules and these breakers may be controlled via CEBus signals on the main power. In addition, significant savings in cabling in new residential and commercial installations can be achieved when CEBus-compatible lighting and appliances are on the market.

The second microcomputer inside the building serves in part as the input/output terminal of the system, allowing the customer to set up a parameter and query the system for power usage information. This displays the reports requested by the customer and also displays messages sent by the facility company and any one microcomputer. The first microcomputer acts as a master controller, communicates with the world outside the building, becomes an operator of the module with a primary data collector, and a rod control, and the second microcomputer acts as an input/output subsystem (receives customer input, provides or displays messages and reports to customers), and provides specific backup functions. If desired, it may act as a secondary controller. As an option, the first microcomputer may also be used as a server for communicating via a network/bus. These devices may be dump terminals (or intelligence units). As an example, the device may be a communication port for various media, wherein the first microcomputer acts as a router between these ports, or between certain ports and one or more dump terminals or intelligence units. Another example may be a portable device in communication with the first microcomputer, and the first microcomputer provides programs, computational support, and other functions that may reduce the cost of the communication or portable device; that is, the portable device may utilize capabilities already present in the first microcomputer. Examples of such portable devices may be game players or cable television controllers. For example, the cable television signal, particularly when it is a compressed and scrambled digital signal, may be rooted in the first microcomputer for decompression and/or descrambling, and then converted to an analog video by means of a board (such as a creative laps Inc., TV Coder) on the internal bus of the first microcomputer. The analog television signal can then be supplied to a home television set. When the digital television set is available, the compressed or scrambled digital signal may be rooted in the first microcomputer for decompression and/or descrambling, and then the decompressed, descrambled digital video signal may be supplied to the digital television set. The portable controller can be interfaced with the first microcomputer via a PLC or RF CEBus or other communication channel to indicate to the first microcomputer a user0desired channel (program) to observe or a user-desired service to obtain. The first microcomputer may execute a program to demonstrate user rights and communicate with the cable television company's computer to provide bills or other information. This allows for greater availability in ordering and providing cable television programming; for example, a pay-per-view system is easily created when the first microcomputer can send a message to the cable television provider about the channel selected by the user, the time covered by the selection, and other information the provider wants. The dedicated text message may be exchanged between the user and the cable television (or other information) provider, allowing the customer to view his count information through the display of the

television or second microcomputer. The portable controller may be used to select from the available functions that can be implemented in the first microcomputer, such as creating a picture-in-picture display, and then the first microcomputer may execute the necessary processing to provide the selected function.

By monitoring the power consumption of the individual rods as well as the overall building, the customer can handle the information that allows the customer to make decisions regarding rod usage. These decisions may be adjusted according to the speed(s) imposed by the electrical installation, which may sometimes be broadcast to the customer by the installation. The facility company may also control at least a portion of the customer's load by means of a message to the first microcomputer when the customer signs up for or engages the facility company to perform such services.

The system of the present invention also utilizes independent rod management. Completely independent, the system can be used as a device-to-device communication interface, on the one hand, in a primary or commercial building, and on the other hand, as an information or service provider or facility.

As described below, it is understood that an equipment company includes equipment that distributes power and may or may not be a direct generator of that power, unless otherwise indicated from a contextual relationship. However, many of the features of the present invention are similarly valuable to other equipment and non-equipment service providers.

The above and other features, advantages and objects of the present invention will be described in detail with reference to the accompanying drawings.

[Simple Description of the Drawings]

Drawing 1 is a block diagram of an exemplary embodiment of a system according to the present invention.

Drawing 2 is a block diagram of a first microcomputer according to an example embodiment of Drawing 1.

Drawing 3 is a block diagram of a second microcomputer according to an example embodiment of Drawing 1.

Drawing 4 is a combination block diagram and a high-level software process diagram/sequence diagram for a first embodiment of a program running on the microcomputer of Drawings 2 and 3.

Drawing 5 is a diagrammatic illustration of a first data structure according to the above embodiments.

Drawing 6 is a diagrammatic illustration of a second data structure according to the above embodiments.

Drawing 7 is a diagrammatic illustration of a third data structure according to the above embodiment, in particular for commercial building use.

Drawing 8 is a diagrammatic illustration of a fourth data structure according to the above embodiments.

Drawing 9 is a diagrammatic illustration of a fifth data structure according to the embodiment.

Drawing 10 is a diagrammatic illustration of a sixth data structure according to the embodiment.

Drawing 11 is a description of an exemplary input screen according to the present invention provided by step 36C of Drawing 4, for allowing a customer to select a particular function.

Drawing 12 is a description of an exemplary input screen according to the present invention for allowing a customer to enter certain device-specific information.

Drawing 13 is a blind view of an exemplary input screen according to the present invention for allowing a customer to schedule a particular event.

Drawing 14 is a description of an exemplary input screen for allowing a customer to remove a load device from the system.

Drawing 15 is an illustration of an exemplary input screen for allowing a customer to enter an energy rate.

Drawing 16 is a flowchart of sub-systems to be executed on the first microcomputer to sync the data structure of the first and second microcomputers.

Drawing 17 is a flowchart of sub-systems to be executed on the second microcomputer to sync the data structure of the first and second microcomputers.

Drawing 18 is a combination block diagram and high-level software process diagram/sequence diagram for a second embodiment of a program running on the microcomputer of Drawings 2 and 3.

Drawing 19 is an illustration of an exemplary screen for use by a user of the present invention to select from available functions within the operator selection module of Drawing 18.

Drawing 20 is an illustration of an exemplary screen showing a meter reading as the user selects the reading meter function on the screen of Drawing 19.

Drawing 21 is an illustration of an exemplary screen showing a selection available when a user selects the reporting function on the screen of Drawing 19.

Drawing 22 is an illustration of an exemplary screen showing daily load and demand reporting when a user selects the form of the report on the screen of Drawing 19.

Drawing 23 is an illustration of an exemplary screen showing a selection available when a user selects a graph function in the screen of Drawing 19.

Drawing 24 is a schematic circuit diagram of a rod control module according to the invention for monitoring the current in multiple branch circuits and turning on or off the rod device remotely.

Drawing 25 is a flowchart of an exemplary program to be executed within the microcontroller of Drawing 24.

Drawing 26 is a schematic circuit diagram of a rod control module according to the present invention for monitoring power consumed within a plurality of branch circuits.

Drawing 27 is a flowchart of an exemplary program to be executed within the microcontroller of Drawing 26.

Drawing 28 is a flow diagram of an exemplary program to be executed within a first microcomputer to implement a load shedding function.

Drawing 29 is a copy of an exemplary output screen according to the features of the present invention showing plots of the average energy use of the customer as a function of time over a day cycle, measured over time intervals that are significantly longer than a day, matched for plots of the customer's actual energy consumption during the same day.

Drawing 30 is a description of a graphical report that may be provided by the present invention for displaying costs incurred by a customer (e.g., family) for a predetermined period (e.g., a week) for each monitored rod and for electrical energies collectively used by all non-monitored rods.

Drawing 31 is a description of a graphical report that may be provided by the present invention to represent the total electrical energy cost generated by a customer (e.g., family), and the distribution of all electrical energy used collectively by each of the monitored rods and by all non-monitored rods, as a function of time of day.

Drawing 32 is a description of a graphical report that may be provided by the present invention to indicate the average cost of electrical energy generated by a customer (e.g., family) for a selected day, to collectively mobilize each and every monitored rod.

Drawing 33 is a description of a graphical report that may be provided by the present invention to represent the cost of each month year for electrical energy used to operate a selected monitored rod, such as an air conditioner.

Drawing 34 shows a description of a report similar to Drawing 30, suggesting that the reporting period is 1 year.

Drawing 35 is a copy of an exemplary output screen according to a feature of the present invention showing a so-called energy usage speed indicator.

Drawing 36 is a copy of an exemplary output screen according to the present invention showing a customer's daily electrical energy usage.

Drawing 37 is a copy of an exemplary output screen according to the present invention showing the distribution of a customer's load duration for a day schedule, i.e., how the energy was consumed for a long time at a given level (shown as a fraction of the maximum value).

Drawing 38 is a flowchart of a program according to the present invention for execution in a first microcomputer for turning on or off a load device according to a set condition.

Drawing 39 is an overall time preset by a customer and/or facility company. A flowchart of a program according to the invention for execution in a first microcomputer for turning on or off a load device subject to a date or cost limitation.

Drawing 40 is a net diagram of a program according to the present invention for execution in a first microcomputer for turning on or off a load device according to a pre-set overall time or energy cost limitation by a customer and/or facility company.

[Detailed Description of Invention]

Referring to Drawing 1, a block diagram of an exemplary implementation of an energy management system according to the present invention is shown. The system (10) includes a customer's building external unit (CPEU) (12) with a communication interface unit (16) and a first microcomputer (18); a local network communication medium (20) a second microcomputer (22) that is a power line carrier (PLC) bus in the exemplary form described below; multiple load sensing and/or load control modules (24); one or more condition detectors (26) (e.g., on-degree sensor, motion sensor, burglar alarm, etc.); and a computer program (hereinafter, in detail) executed on two microcomputers to implement various functions having one or more functions described below. Preferably, the system also includes an electronically-readable watt-hour (i.e., energy usage) meter (14) through which power is supplied from the AC dispensing main power (15) to the rest of the system. The load control modules (24) may be in different forms, for example, some of which may be simple on-off switches and others may comprise current or power sensors. Additionally, the system optionally includes one or more other specific single- or multi-use input, output, or input/output devices (generally shown as reference number 27), all using a bus (20) for communication with the first microcomputer and utilizing the computing power of the first microcomputer to enable certain desired programs to be executed. These add-on devices can meet the communication and information needs of the customer in a variety of different areas.

In all cases, the supply of AC power to the computer, rods on the bus and other devices are omitted for simplicity of description. In addition, each computer or other device must have a bus interface unit for connecting to the bus, implement the bus protocol; these interface units are implicit and are not clearly shown to prevent complexity.

Both of the two microcomputers are, for example, IBM-compatible personal computers running versions of IBM or Microsoft's DOS operating systems on an Intel x86 family processor, a power PC family microprocessor, or processors thereof. In an exemplary embodiment, the first microcomputer uses a power PC 403GA built-in controller of International Business Machines Corporation (IBM), based in Armonk, NY, and Research Triangle Park, NC, as a processor, and the second microcomputer is expected to use certain Intel x86 family processors and the like, both of which may run versions of the DoS operating system and may be interrupt-driven; however, it is particularly preferred when the first microcomputer acts as a server, as discussed herein, the first microcomputer executes a multitasking operating system, such as IBM's OS/9 operating system, using a program recorded in the Ultra C programming language of the Microware System Corporation (Des Moines, IA). Of course, other processors and operating systems may be used; the selection of processors and operating systems is not an important feature of this invention. However, the use of industry-standard microcomputer architectures reduces costs and has the advantage of making various input/output components such as modem, router, bridge router and other communication products readily available. The block diagram of the first microcomputer is shown in Drawing 2. As shown in the drawings, a microcomputer (18) includes a microprocessor (18-A), memory (18-B), at least one input-output (IO) device (18-C), one or more computer programs (18-E) running on the microprocessor (18-A), and one or more internal buses (18-D) enabling these devices to communicate. The computer program (18-E) interactively operates with data in a data structure stored in the memory (18-B) to control the operation of the first microcomputer. The input-output (IO) device (18-C) includes at least one device for communicating with the facility company, one device for communicating with the second microcomputer and the load control module, and one device for querying the watt-hour meter. If power-wire carrier technology is used to perform all these communications, it may use a single I/O device (18-C); otherwise, individual I/O devices may be required for one or more of these communication services. The connectors are provided on a bus of one of the buses (18-D) to accommodate, for example, a plug-in circuit card frame for an I/O device. Buses and connectors preferably correspond to industry standard interfaces such as ISA or PCMCIA standards. For example, an ISA radio frequency network interface (including transceivers and control logic) card may be plugged into one connector (18-F1) for use in communication between the system stem and the facility company, and a CEBus interface node (i.e., transceiver and control logic) may be plugged into another connector (18-F2) for use in communication between the first microcomputer and the load control module. Memory (18-B) preferably contains a certain amount of non-volatile memory, which may have a stored data structure with hi-stories data preferably included, particularly during power outages and interruptions; flash RAM is believed to be suitable for such use, even though other memory types are satisfactory. The first microcomputer does not require a keyboard, nor a display (except that it is optionally provided for installation and fault diagnosis purposes). Preferably, this is included in the waterproof and sealed housing at the entrance of the electrical service to the building, on or immediately adjacent to the client's building facade next to the watt-hour meter.

The block diagram of the second microcomputer (22) is shown in Drawing 3. As shown in Drawing 3, the second microcomputer (22) includes a microprocessor (22-A), a memory (22-B), a user-interactive I/O subsystem or device (22-C), which communicates via one or more internal buses (22-D). Computer programs (22-F) are executed by a microprocessor (22-A) to implement the functionality of the microcomputer (22). The second microcomputer may be placed in a predetermined convenient location in the customer's building. If an appropriate network/bus interface (e.g., CEBus PLC interface) for communicating with the first microcomputer and an appropriate computer program described are provided, this may actually be a microcomputer that the customer already owns.

The user-interactive I/O subsystem (22-E) is executed by a microprocessor (22-A) to implement the functionality of the microcomputer (22), for example, displaying a visible output and receiving input selection from the user. The second microcomputer may be placed in a predetermined convenient location in the customer's building. If an appropriate network/bus interface (e.g., CEBus PLC interface) for communicating with the first microcomputer is provided, and an appropriate computer program described, it may actually be a microcomputer that the customer already owns.

The user-interactive I/O subsystem (22-E) may include, for example, a touch screen (22-E1) for displaying the visible output and for receiving input selection from the user. If desired, a keyboard (22-E2), voice recognition, or other input device (not shown) may also be added. (Although all I/O subsystems are shown as communicating via the bus(es) (22-D), it will be appreciated that this is a common practice with respect to a keyboard for communicating with a microprocessor via a particular keyboard handler not shown to avoid a detailed description unrelated to the understanding of the present invention). The I/O device (22-C) includes at least one device for communicating with the first microcomputer, and as described above, preferably the power-line carrier technology is used to perform all of these communications. The connector (not shown) may be provided on one of the buses (22-D) to receive, for example, a plug-in circuit card for an I/O device. Bus and connectors are well aligned with industry standard interfaces such as ISA or PCMCIA standards. For example, the CEBus interface may be plugged into one such connector for use in communication with the first microcomputer.

The system of Drawing 1 uses a first computer program CPEU_PGM operating the first microcomputer and a second computer program USER_PGM operating the second microcomputer. The CPEU_PGM program is the main control program. It initializes load (current and power) monitoring to store historical data to perform a total power meter (watt-hour meter) reading, executes the requested load turn-on/turn-off events, and monitors communication from facility companies. In addition, various other functions specified herein may be performed, or these other functions may be achieved by other programs that may be performed simultaneously under a multi-testing operation system or optionally executed in response to appropriate interrupt signals. The CPEU_PGM program is the system and customer interface: This program may need to assemble historical data from the CPEU_PGM program to format that data into a report for the customer to schedule the time of the turn-on/turn-off event state and use multiple second microcomputers, each running the CPEU_PGM program for execution of that state. In this configuration, the first microcomputer executing the CPEU_PGM program serves as a file server and becomes a central part of the information and control system with internal and external sources of information and communication services.

A high level software process schematic/flow diagram is shown in more detail in Drawing 4. The structure of the CPEU_PGM program (34) is shown on the left side of the dashed line (30), and the structure of the USER_PGM program (36) is shown on the right side of the dashed line (30). Communication between the CPEU_PGM program and the USER_PGM program is represented by a line (32).

The CPEU_PGM program (34) is a process data request module (34A), a process load shedding request module (34B), an incoming current energy pricing information module (34C), and a poll and store module (34D). Includes six modules of a control unit module (34E) and a scheduled event module (34F). These six modules are executed sequentially with loops as shown. However, during each module execution, the entire task assigned to the module is not completed and one segment of the task is completed. The segment typically completes module actions for one device, event, or other suitable quantum. For example, the pole meter module (34D) initiates a reading of the total power meter by generating a CEBus irradiated message during passage of the first module and initiates a timer to set (set) a status flag (not shown) in a predetermined memory location to indicate that the reading has been initiated. Upon continuous passing of the module, the status flag is checked and determined to be in this set, and the flag resets after the reading is complete and the data is retrieved. Similarly, the term module (34E) is processed for each pass with only one entry in the typical DEVICE data. In this case, the device pointer, as described below, is written to the selected memory location and is used to control the operation of the module from pass to pass. The device pointer identifies the device to be processed by the module on the next pass. It is updated after each module passes. The pointer is also used to segment control of the scheduled event and load (device) distribution. These segments of the module work control the path to potentially more urgent tasks, such as proper reception of load balancing commands, by avoiding processing delays that occur in the case of tasks that require seconds to complete the initiation. The operation of the module (34A- 34F) will be described in more detail below.

The USER_PGM program (36) includes eight modules (36A-36H) with more complex interrelationships. From the synchronous circuit with the CPEU_PGM program (36A), it is controlled by the display history and menu module (36B). The monitor module (36D) for display current usage operates from or within the operator selection module, shows current power usage and other selected information in one part of the display screen, and shows operator selection available from the operator selection module in at least one part of the remainder of the screen. Following the receipt of the operator input obtained by the operator selection module (36C), one or more of the four modules (36E-36H) are executed to perform appropriate action in response to the action input. An additional controlled reporting device module (36F) adds one device (i.e., a load) to the system that is controlled by the system or reported to the system. The deletion device module (36F) removes the device (i.e., load) controlled by or notified to the system from the system (i.e., the data structure discussed otherwise). The add-on/delete on/off event module (36G) records any variations to the event over time or conditions to the system control storage device to turn the load on or off. In addition to the device being on and off, if the device can be dimmed (any X10 type optical controller and CEBus dimmer module, such as Intellon TCM1036 module, etc.), the on/off event may include a field for setting a dimming level (e.g., full scale speed) for the device (X10 protocol is a commercially set standard PLC control device and is an alternative to the CEBus protocol). Finally, the display reporting module (36H) displays any report requested by the customer onto an output device of the second microcomputer. From the module (36E-36H), if there is information to be exchanged, the control is returned for synchronization with the CPEU-PGM module (36A) to transmit data to or receive data from the CPEU_PGM program (34).

Before returning to the description of the CPEU_PGM module, information about the load of the customer premise and the energy and power usage of the fully deployed load is maintained in the data structure or the structure shown in 38 (Drawing 4) and physically placed in the memory (18-B). When it is on, the second microcomputer has a substantially redundant set of data structures (39) in memory (22-B) (memory (22-B) preferably RAM Eh includes a hard disk drive or other non-active storage medium (22-B) for holding the data structure (39) in addition to other temporary storage devices). When discussing these data structures, the following conventional structures are used: The name of the data structure is given using uppercase (lowercase will be used throughout the drawings), and the name of the parameter is given in the drawings using italics (Romanized, used in drawings).

Referring now to Drawing 5, the first data structure (42) CUSTOMER comprises multiple fields, such as cost_kwh field (42A), customer name field (42B), address addr field (42C) of the customer, and energizing speed or speed code when the account number acct field (42D) of the customer is charged to the customer. (The size of each field is a matter of design selection, and in fact a given field, such as an add field, may be divided into smaller pulses for configuration information, such as zip code portions of streets, cities, states, and addresses. If multiple speeds are applied to a customer's bill, such as a different rate of power consumed in over time of day, to switch between applicable speeds, in this case a more cost-kwh field exists, the facility company may broadcast a command to switch another field to select the rate, or the CUSTOMER data structure may have a field that relates the cost-kwh field to the associated time it is applied to.

The second data structure (44; Drawing 6) device is arranged as a data structure with one entry per load to be monitored or controlled. For each load, the data structure preferably contains the following information in a separate field, the device power normally consumed when turned on in watts (44A), the current consumed normally when turned on in amps (44B), the voltage across the device when turned on. volt(44C), output factor of the device if it is a reactive load power_factor(44D), code indicating the type of load the device is for example resistive, inductive or fluorescent load_type(44E), for load balancing operation (to be described later) Priority code of the device used (priority 44F), first address code code-number 44G, which may be used as the number field of the address of the device for X10 type devices, character field of the address of the device for X10 type devices second address code code_letter (44H), which may be used as a house code for CEBus type devices, third address code cebus_unit (44J), which may be used as a house code for CEBus type devices, description of the device (text) provided by the customer desc (44K), customer text status of device location given by location(44L), device current on/off or other status status(44M), count current-hours(44N) indicating how long (cumulatively) the device has been on in the day, count mtd-hours(44O) indicating how long (cumulatively) the device has been on for the current month, count last_month (41P) indicating how long the device has been on during the last month, how long the device has been on for one year up to the current day It actually holds a count yid-hours (44Q) indicating, and a flag cebus-noack (44R) indicating to the CEBus device whether to provide an ACK signal. Any of the above fields that may be added as additional fields are required and not required in a particular embodiment (described examples of embodiments) may be omitted. Of course, the data structures shown in the drawings are merely illustrative. For example, multiple instances of a pair of fields (#A and 44B) may be provided to a device

capable of multiple consumption levels (e.g., multi-speed motors). Those skilled in computer programming can recognize the data structures depicted using an indication of the C-programming language. However, using the C language is not meant to be limiting, but a conventional programming language may be used to carry out the process and data structures of the present invention.

In an example embodiment, data in a field (44N-44Q) may be quantized in any easy size unit, which is a matter of design choices as to how often data should be sampled and stored, and it is believed that an interval of 30 seconds per storage event provides a suitable trade-off between the amount of memory that is available in the report and the amount of data and information that needs to be stored. In other words, the total power meter output tick generated per predetermined energy consumption is accumulated and the power meter is read and stored in a data file once every interval, e.g., once every 30 seconds.

For customers or others with major reactive loads, the DEVICE data structure may be added with (or replaced, if necessary) the COMMERCIAL data phrase (48) (Drawing 7). Such data structures include, for example, calculations of the consumption of the device over a selected interval, identification of the interval by interval number or time (e.g., year (49A), month (49B), day (49C), hour (49D), and location in time (49G)), an interval size in minutes (49G), the number of minutes (49L) or equivalent load time in which the load is on or off during the interval, the urination during the interval (i.e., kwh hours 60 minutes divided by the interval length in minutes) (48K), the associated meter identification number (48F), a meter reading at the end of the interval (48M), and the length of the interval if the interval is not determined (48kwh). Data and time fields are optional because the data structure may be self-indexing for date and time. When a recording is made, for example every 15 minutes, using flash memory as a circular column, the location in the column (i.e., the address in the memory of the entry associated with the current entry) clearly indicates how long the entry has been relative to the current data and time. With a 15-minute recording interval, only 2MB of storage is required to record two years of data.

Referring to Drawings 8-10, the additional data structure retained by the system includes a meter history table (MERE;52), a device history table (DEVICE HISTORY;54) and a TIMED (i.e., scheduled) EVENT list [(56) also referred to as an event table] for at least each device on which the power arsenic ratio is monitored.

The METER table (52) includes, for example, a field (53A-53H) that records information related to each meter reading. Such information may include some or all of the CEBus house (or commercial building) code CEBus_hc (53A) forming a first portion of the electronic address of the meter, the CEBus unit code cebus-unit (53B) forming a second portion of the electronic address of the meter, the final meter reading current (53C) recorded, the first meter reading current_start (53D) during a corresponding time in a first table having 24 entries per hour of the day, the final meter reading current_reading (53E) during a corresponding time in such second table, the accumulation energy mid (53F) used in that month except for the day of the hour in such third table, and the total energy ytd (53H) used for the entire year in the fourth table except for the day of the hourly.

The DEVICE HISTORY table (54; Drawing 9) (one per monitored device, preferably named 55A in the table) stores records that contain data arranged in a selected pattern at each measured interval. To more vividly describe the configuration of the data structure, it is schematically illustrated without using C-code. Each record includes a field that records one or more of the following measured voltages volts (55B), in-phase current (in_phase) (55C), reaction current (reactive) (55D), kwh kwh consumed within the interval (55E), kvah kvah consumed within the interval (55F), and kvarh kvarh consumed within the interval (55G) for the additive load. If the address (i.e., the first entry) of the table for recording is correlated with the date and time of the table entry (e.g., via indexing schemes), it is necessary to record the date and time as part of the recording, since they can be computed. For example, if a table entry is made every 15 minutes, and a continuous entry is made at a continuous location, it can be easily verified that the entry before the tenth of the current entry is made at intervals related to 150 minutes ago. If the device voltage can be assumed to be a constant value, the field bolt should be provided only once in the table, not when writing. Thus, if the measurement of the device consumes 8 bytes per field and the set of measurements (including kwh, kvah, and kvarh) is stored every 15 minutes, the two-year history for the device may be stored at about 1.7 MB. This can be reduced by not storing kvah, and instead computes it from relationship $(kvah)^2 = (kwh)^2 + (kvarh)^2$. If the recording address of the table is not indexed by the above method, it must be included in the record field containing the date and time interval. Each field recorded in each record consumes a little more than a half megabyte to cover a two-year interval.

The structures shown in each of the data described herein are illustrative only, and other suitable data structures will become apparent to those skilled in the art and to computer scientists assisting them. Since it is understood that other customers may have different information needs, other suitable data structures can be formed and maintained, including multiple hybrids of DEVICE and COMMERCIAL data structures.

Drawings 11-15 describe some of the screens presented to the customer in the dispatch or greater of the second microcomputer (22) in order to achieve the entry of user-customizable parameters.

If the display of Drawing 11 is provided by step 36C (Drawing 4), select the button, such as the device add μ button (62), to allow the customer to select the option. Once the device add button is selected, the screen of Drawing 12 with several data entered into the customer in the conventional method is presented, followed by the customer saving the entry using the F10 key. If the customer selects the schedule event button of Drawing 11, the screen of Drawing 13 is presented and the customer is allowed to enter the appropriate data. When the customer selects the Delete Device button in Drawing 11, the screen in Drawing 14 is presented to allow the customer to select and delete the device. If the customer selects the Enter New Rate button in Drawing 11, the screen in Drawing 15 is presented and the customer is allowed to enter the new energy cost, cost-kwh.

Two microcomputers (18 and 22) will communicate via a power line carrier (PLC) link designed over building power wiring based on the CEBus diffuse spectrum protocol using a commercially available CEBus interface from Intellon, Ocala, Florida. The first microcomputer also uses the same PLC system with a load (device) control module capable of, for example, enabling or disabling an electrical water heater. It can communicate with a sensor that can detect when the device is operating; it can also communicate with other sensors and actuators. In particular, the total power meter may be retrieved by the first microcomputer to monitor the energy consumption of the building. The first microcomputer (18) may also communicate with the power company via a suitable communication interface (16) and associated channels such that it receives a real-time energy charge broadcast, load shedding request, and the like, and transmits power shutdown reporting, low power state reporting, customer usage reporting, and other optional data to the ship company. The communication channel may be, for example, an electrification system, a cable television system, or a radio frequency link; it may also be a power line carrier (PLC) system, such as a variation of the technology traded by Elcon.

With the CPEU-PGM program (34), the process data request module (34A) processes the handling and response of data input and output requests from inside the second microcomputer (22). These requests include scheduling changes, device additions and deletions, and historical data requests. The module (34A) also supplies the second microcomputer (22) with information, such as asking the customer to generate a report. The Process Load Segmentation Request Module (34B) is when a load segregation request is reached from the facility company and a response control message is generated through the CEBus system to a load that is instructed to turn off or resume normal operation. This load sedation request is processed. The current energy cost information receiving module (34C) receives an energy cost alert from the facility company or from a customer, for example by keyboard entry from the screen of Drawing 15. The poll and storage module (34D) poll the total power meter to obtain current requirements and accumulated energy consumption since the most recent previous poll; they also poll the monitored device and store the result. The control unit module (34E) using cost information executes a conditional device control operation that depends on the facility-charge (see description related to Drawings 38-40). The scheduled event execution module (34F) runs a scheduled on/off event based on user-supplied timing schedule or cost-generating customer setup conditions, as its name means, unless the execution of the event is canceled by an ongoing load setting action. Scheduled events include, for example, turn-on of the load, turn-off of the load, thermostat reset, and variations in brightness due to changes in dimmer settings.

The order in which modules (34A-34F) are executed can be mutually changed depending on the degree of importance when the overall time of loop execution is short.

The USER-PGM program (36) requests historical data from the CPEU-PGM program (34) and then formats this data into a report (preferably a graph representation). In addition, the customer is entered into the USER_PGM program (36) schedule for on/off events, which is transmitted to the CPEU_PGM program (34) for execution by the module (34E). The display history and menu module (36B) are displayed on the currently selected screen.

The first and second microcomputers (18 and 22) differ in one important respect. The first microcomputer is always on whenever there is voltage present in the ac supply cable for the building. It is preferred that the first microcomputer receive power directly from the power line of the sermon company outside the building. Conversely, the second microcomputer may be a conventional personal computer that can be turned on or off at the customer's discretion. This means that the second microcomputer does not have the latest data compared to the data held in the first microcomputer. Thus, the synchronous program module is executed on the first and second microcomputers to ensure that reports generated by the second microcomputer from the data structure are based on accurate information. Drawings 16 and 17 provide flow charts of exemplary synchronous processes running on first and second microcomputers, respectively. In order to prevent the formation of unnecessary traffic on the bus (20), a determination is made to update the second microcomputer's data structure incrementally and mostly on demand. The second microcomputer may request data for a usage interval of 10 times at a time (or another predetermined exponential). As soon as the booting is up, the request is made and continues to be made during the execution. If the second microcomputer is stopped, turned off, or hung up, the first microcomputer will soon stop transmitting data because the first microcomputer cannot receive it. To do this, the second microcomputer maintains a counter called a usage transmission counter (not shown), wherein the data records a count of the meter reading interval that was not transmitted to the second microcomputer. The first microcomputer periodically executes a usage counter transmission (step 64A) and, if the content of the counter is non-zero, determines whether the new interval data is ready for transmission (step 64B). If there is data to be transmitted, it is transmitted (step 64C) and the usage transmission counter is decremented (step 64D). If the content of the usage transmission counter is zero or there is no data to transmit, or if the data is transmitted or the counter is decremented, the first microcomputer searches for which synchronization request was received from the second microcomputer (step 64E).

For example, the second microcomputer (22) may request to inform the first microcomputer of an event or device change written by the customer, and if there is no request from the second microcomputer (22), the synchronous process is instantly terminated (step 64F). When a drive request is received, the system determines what kind of request it is (step 64G). The following possible requests represent those that may be received: The second microcomputer may request history data (including data, time, and power and current measurements-all buildings and/or individual devices) since the last information (step 64H). Alternatively, if the second microcomputer cannot find the device table or if the device table is modified, it may request that the entire device table be transmitted (step 64I). Similarly, if the event table of the second microcomputer is lost or modified, a new event table may be requested (step 64J). If the second microcomputer finds a different loss of information, several types of information requests can be made (step 64K). If a customer adds or deletes a device or event, a request to supply this information to the first microcomputer may occur (steps 64L and 64M), respectively. Following each request (64H-64M), a suitable operation is taken to supply the information specified in the corresponding steps 64N-64S, followed by a synchronous routine from the first microcomputer. Finally, the second microcomputer may indicate that the execution is starting or that the next 10 (or other recall) usage intervals are being requested and continued to run (64T), in response to which the usage counter transmission is set to 10,64U, and a routine is generated. The amount of usage interval transmitted at step 64T includes in seconds the number of kilowatt-hours consumed in the building during the actual length of the measurement interval; optionally, the usage interval can contain data at the time of individual device consumption. The measurement interval is normally 30 seconds, but the actual length of each measurement interval may differ from the nominal value because the microcomputer may be involved in other operations at the end of the interval or at the beginning of the interval.

Exemplary synchronous programs (66) for execution on the second microcomputer (22) are shown in Drawing 17, first, the second microcomputer implies data from the first microcomputer (step 66A). If nothing is introduced, the second microcomputer searches for the lost table (step 66B) and, if nothing is lost, requests that they be transmitted (step 66C). If all tables exist, the second microcomputer determines whether the customer has changed to a device date or event table (step 66D) and, if so, sends the change to the first microcomputer (step 66E). In step 66A, if incoming data are present, it is determined for the nature of this data (step 66F). If the data indicates the current history, the history table is updated (66G); if the data is device table information, the device table is updated and stored (step 66H), if the event schedule information, the event table is updated and stored (step 66I); if the data is of different kinds, the appropriate memory location is updated (only 66J); (30 seconds), if the data is usage data, the information is sent to the display screen or stored in a temporary repository (step 66K), then the count is checked (step 66L), and if the count is written down, a different group is requested (step 66M).

Returning to Drawing 18, another embodiment of the invention is described. This example is not particularly intended for use in commercial buildings where a plurality of total power meters can be used, rather, detailed information from device to device is desired. It is assumed that each total pre-power meter contains non-volatile memory that records and stores the metric read. Again, the system runs on two microcomputers (18 and 22) running two different programs (72 and 74). The program (72) has four modules (72A-72D). The module (72A) is similar to the module (34A) (Drawing 4). The meter type is determined for each meter system, and the initialization module (72B) reads the meter type code and executes necessary initialization. In particular, this initialization may vary depending on the characteristics of the integrated power meter. Once initialization is complete, a loop is executed that includes the module poll metric (72C) and the update history file (72D). The poll meter module (72C) periodically polls each total power meter through CEBus and makes the reading valid for the update history file module (72D). Next, the update history file module (72D) updates the metric history file and waits for the next poll. The program (74) is able to read the historical file maintained in the data structure (38) at any time.

The use of a plurality of meters is of course not limited to commercial buildings. Thus, this program (72) may be coupled with the first embodiment of the invention. Similarly, the plurality of communication systems described in connection with the first embodiment of the present invention may be used in another second embodiment of the present invention.

The program (74) is assembled into 16 modules (74A-74P). The module (74A) communicates with the data structure (38) via the program module (72A) and supplies the program (72) with a history of power consumption for the meter. The operator's selection module (74B) is executed after the synchronous module (74A); and causes this modular customer to select one of four categories; metric reading 74B-1; report generation 74B-2; graphic 74B-37 of the data or processing 74B-4 of the file. A typical screen presented by the operator's selection scheme is shown in Drawing 19. When the metric read option is selected, the read history file module (74C) control proceeds. The reading history file module (74C) reads a history file for a predetermined number of reads, such as the last 10 reads, to obtain a current metric read. The display module (74D) displays on the screen information read by the module (74C), for example, as described by the screen shown in Drawing 20. When the reporting option (74B-2) is selected, the control proceeds to a selection module (74E) which displays a list of valid reporting forms to the user and requests the user to enter a selection (see, e.g., Drawing 21). Once the selection is made, the print reporting module (74F) prints the report using the current data. As an example of a valid report at this stage, Drawing 22 describes a time lump report of daily loads and needs for a day. When the graph option (74B-3) is selected, control proceeds to a selection module (74G) which displays a list of valid graphs to the user and requests the user to enter a shunt (see, e.g., Drawing 23). Once the selection is made, the desired graph display module (74H) uses the current graph to display the graph and, if valid, allows the operator to select the printing of the graph on the attached printer. When the file processing option (74B-4) is selected, the control proceeds to the Edit 1 Record or Read Selection Module (74I) which displays a message requesting the operator to select from the valid options: Edit the history file, record the current history file in the standard data format, or read the current file from the facility company. When the user selects the edit option, the History File Module (74J) displays the History File from the memory to allow the user to edit the data. When a user selects a recording option, the standard data file recording module (74K) records the file containing historical data in a format that the user selects an output data format, for example, acceptable by a diffusion sheet or database program. When the user selects the read option, the standard data file read module (74L) allows the currently saved data to be entered into the computer of the power company into the history file used by the programs (72 and 74). After the selected option finishes running, the control switches to the operator's selection module.

Load Control Module

While the three forms of load control modules are specifically named, it will be understood that the present invention is not limited to these exemplary modules. The three modules described below are the current sensing module, or monitor, power sensing module, and circuit breaker. The circuit breaker may be a single module or may be coupled to one of the other forms of modules. In the example described below, the circuit breaker is provided as part of the current sensing module; and not because individual descriptions of the isolated circuit breaker are unnecessary,

Current Monitor

An exemplary current sensor is shown in Drawing 24. The current sensor (80) is a power source (82), a power line carrier coupled circuit (84), a PCL bus interface (86), and a microcontroller (88). For each current level to be detected, A processing channel comprising current transformers (92-1) (variable I refers to the channel identifier) and current sensing circuits (94-1) each having or sharing a threshold set element (96-j) (only one current sensing circuit (94-1) is labeled on the drawing). The output of the current sensing circuit is read by the microcontroller. The microcontroller also implements a CEBus Common ApplicationLanguage (CAL) to determine the behavior of the sensor, such as whether the microcontroller firmware language (not shown) should be polled to determine and measure its state or should automatically report the state or the report of observed values.

This current sensor is used to determine whether the current of the branch sensor (branch sensor) exceeds a preset threshold. The threshold for the current sensing circuit may be fixed or variable. Typically, the current monitor is fixed if it is embedded within the application, and may be variable if it is distributed as a general purpose product that can be adapted for use with various load elements. The branch circuit is a power distribution circuit having its own circuit breaker (or first setting, fuse) in the building electrical distribution panel. Major applications, such as clothing dryers, cooking stoves or ovens, refrigerators, air conditioners, hot water heaters or cooling pumps, will often have its own powder circuit. In some applications, as described below, to monitor the current, one branch circuit may be treated as a multi branch circuit. In a basic setting, the threshold value may be set relatively low, where the sensor indicates that if only one load is for the branch circuit, the load is drawn current (i.e., turned on). On the other hand, if it is the only load on the branch circuit but the load can be operated in different modes, such as a low power mode and a high excitation mode, the threshold can be set at a level between the currents drawn in the two modes. The sensor output will indicate if the load is operating in high power mode at this time. The monitor is not intended to provide a quantitative measurement of the current in the branch circuit.

The circuit (80) may monitor up to six branch circuits (112-1 to 112-6), one for each microcontroller port (P1.0-P1.5). Through another port (P1.6), this may control the on/off state of the load. The current sensor (80) is designed to communicate using CEBus power line carrier signaling. For this purpose, the sensor (80) is equipped with Intellon's CENode PL (pole, power line) interface module (86). The Model 87C751 microcontroller (88) of Signetics, Sunnyvale, CA, controls and generates signals sent to the CENode PL module and performs an operation according to signals received from other CEBus devices. The circuit (80) is preferably mounted to or adjacent to the building electrical distribution panel. In order to monitor one load, a subset of the monitor (80) may be packaged to insert into the module that is flushed into the ac power receptacle with the housing interior of the load or the load device plugged into the module.

The power supply (82) supplies +5 volts dc (VDC) for the current monitor from the main AC power connected to the terminals (83A and 83B). The circuit preferably has a transducer T1, propagation rectifier B1, electrolysis filter capacitor C1ZD11 and ZD2 connected in series to both mains as a surge protector. The transforming group T1 supplies a 10 volt 600 ma output and shows up on the line (102) for the microcontroller (88) and the comparator (104-1) where the unadjusted 5VDC output is discussed below.

The power line carrier coupling circuit provides a connection between the PLC bus interface (86) and the power line itself. The PLC coupling circuit is provided with a transducer T2 having a first winding connected to the power line via a series capacitor (106) (relatively to filter relatively low frequency ac power signals from high frequency PLC circuits). The second winding of the converter T2 is connected to the signal FO port SSC-SG of the PLC interface module. The protective circuit (108) is also connected between the second winding and the ground.

The PLC bus interface unit may be, for example, a model CENode-PL CENode network interface board of Intellon located in Ocala, Florida, or equivalent (if RF communication is used between nodes, for example, it may also use Intellon's CENode-RF network interface board as a substitute for the PLC system, or the network may be based on standards other than Intellon and the appropriate network interface may be replaced).

The microcontroller (88) may be, for example, a model 87C751 microcontroller of Signetics (Ltd.).

The real current sensing is performed at the current sensing stage (110). The current sensing stage has at least one channel per branch circuit variation to be monitored. If the condition or variable to be monitored depends on the on or off state of the load, one channel will be sufficient. If the load condition to be monitored is in its operating mode and there are low and high power modes outside of C-off mode, two channels will be required. From now on, the operation of one channel (112-1) will be described. In a B5303 rolled toroidal core current sensor CT1 from Bicon Electronics Co., Ltd. of Kaan, the CT is used to create a transducer 92-I, the toroidal core sensor having an auxiliary winding of the transducer; Branch circuit conductor 114-I is wound through the core to provide a primary winding of one turn. The voltage generated in the secondary winding by the current in the branch circuit (main winding) is a half-wave rectified by diode 116-I and filtered by electrolysis capacitor 118-I and resistor 120-I. The comparator (104-I) compares the commutation voltage on the line (122-I) to the reference voltage supplied by the line (124) to the potentiometer (96-1) (where one end is connected to +5 volts power and the other end is connected to ground). The output of each comparator is the input port of the microcontroller (88).

One of P1.0 - P1.5 is connected. When the current of the branch circuit generates a commutation voltage greater than the reference voltage connected to the associated comparator, the comparator generates an output voltage interpreted as a logical high signal, and when the current of the branch circuit generates a commutation voltage less than the reference pre-voltage, the comparator generates an output voltage interpreted as a logical low signal.

In the embodiment shown in Drawing 24, for convenience, two threshold adjustment values are provided, one shared in common by channels (112-1 to 112-3) and the other shared by channels (112-4 to 112-6), at a high cost, each channel may be presented with its own independent threshold adjustment, which may be accomplished by receiving a digital value from a microcontroller and providing an analog value directly to the comparator input.

To illustrate the use of a current monitor to detect the mode of operation of a load with multiple modes, it is assumed that the load is a high speed and low speed pool pump. Referring to Drawing 24, a channel (112-1) may be used to monitor high speed, and a channel (112-4) may be used to monitor low speed. The diverging conductor passes through coil CT1 and CT4 in series. The potentiometer (96-1) will be sufficient for a slow speed operation to trip (thp) the comparator when the pump operates in any mode. The comparator (104-1) is set to a voltage that allows it to trip. However, the potentiometer (96-2) is set to a voltage that does not allow the comparator (104-4) to trip except when the pump is running at high speed.

The definition of tripped (used in the present invention) means that the comparator output is in a logical 1 state.

Drawing 25 is a flow diagram of an operation executed by a microcontroller (88). The block (132) indicates an entry, or starting point, for the operation of the microcontroller. First, the microcontroller determines whether it received a request to an external node via a PLC bus (CEBus) (step 134). Otherwise, the control branches to a short (136) where the microcontroller polls its input ports and internal registers against the signal on the branch circuit.

The next time the microcontroller checks the mode of operation (138). If the microcontroller operates in a so-called polled mode that monitors branch circuits, the control returns to point A, and the process repeats itself. However, If the microcontroller operates in so-called automatic mode, the control proceeds to the step (140) of determining if a state change of any branch circuit exists by comparing the currently read value to the previously read value, and if there is no state change, the control returns to point A. If a state change exists, the control generates a suitable report and passes the report through the PLC bus to proceed to the step of returning the control to point A (142).

If step (134) determines that an external request has been received, the next step to be implemented is step (135). In step (135), a response message is generated when the initial message obtains a response. On the other hand, if the received message is requested or commanded for the microcontroller part, the action is executed.

As such, the microcontroller (88) periodically polls the comparator (104-1 Nash 104-6) in some sequences. If a change in phase is detected in one of the comparator outputs, the microcontroller observes the event and generates a time-stamped entry in the event log. It sends a message to one or two microcomputers via the bus interface. The microcomputer and any other suitably equipped device on the bus may communicate a condition request message to the microcontroller via the bus interface to request the status of the circuit monitored by the one or more devices or the current monitor, wherein the current monitor will deliver a suitable response message. If the requesting device knows the load connected to each of the channels of the monitor, a byte response will indicate the status of up to 8 loads.

In the terms of the CEBus protocol, each comparator is a binary sensor object (the current monitor of Drawing 24) and the seven previous sensor objects that are consistent with the EIA Home Automation (CEBus) Draft ISA (60) are urgent.

Optionally, preferably, microcontroller 88 is also connected to energize relay K1, which supplies ac power to the load (i.e., the relay contacts can be placed in series with the branch circuit). As such, one relay needs to provide load-shedding capabilities. The relay coil is energized by the microcontroller (88) via the transistor driver QK1, wherein the diode D1 protects the transistor from voltage spikes generated inductively when the transistor is turned off. If the microcontroller receives a command to shed the load, all it needs is to stop supplying energy to the relay coil. If the relay contact is normally open in the absence of the coil energy supply, the load will automatically be shed when a power output occurs. A proper software programming in a microcontroller that interacts with a program running on a microcomputer may delay the provision of additional energy (reenergization) until the selected time or random time after the power supply is restored, thereby reducing the stress on the power system.

In the end, the current monitor in Drawing 24 is used as a single branch monitor (i.e., If necessary), by assembling it as a module with a load receptacle to lug and plug into the AC receptacle, the old facility (appliance) can be adapted to be monitored and shed by remote commands. If it is necessary to provide multiple priority levels for optional load shedding, the priority of the individual loads may be set by the microcomputer in a data structure (38) (see Drawing 6) or other suitable data structure, based on the usage particle force. Optionally, the load control module may be read by a microcontroller, such as a set of switches. A user-settable method for recording a priority level may be provided.

Power Monitor

Of course, only on/off mode monitoring cannot provide users with much useful information to determine about reducing energy costs or usage, and monitoring power and energy consumption of individual loads is necessary for the above purposes. Referring now to Drawing 26, an exemplary embodiment of a power monitor according to the present invention is shown. The power monitor (150) uses the same PLC bus interface (86) as the same power source (82) on the current monitor. The microcontroller (152) is a Signetics 87C752 microcontroller similar to the Signetics 87C751 microcontroller of the current monitor, whose use has an analog-to-digital converter (ADC) described below. 87C752

In the embodiment of Drawing 26, one module has multiple branch circuits (assuming there is only one device per monitored branch circuit). It is used to monitor and assumes that all branches receive the same voltage. In a given situation, This assumption may cause an error in the measurement, in which case the measurement is taken to monitor the voltage across each monitored load, i.e., the power monitor circuit should be placed proximate the load. In contrast, the power monitor (150) may be placed on or adjacent to an electrical service panel that is easily accessible to multiple branch circuits. Therefore, concerns about non-uniform branch voltages for completeness are increased and will not be further mentioned. The line voltage is collectively sensed by a line pressure dispenser or attenuator marked 154 and is provided with an amplifier (156) and resistance (158,162,164 and 166). The line voltage is attenuated by a factor of about 50, resulting in an AC signal of about 5 volts peak-to-peak on the line (168) at the output of the amplifier (156). A 2.5 volt DC level is introduced to the node (170) and added to the line voltage attenuated to bias the AC output of the amplifier (156) in the range of 0 to 5 volt DC. The output signal from the amplifier (156), referred to as the VOLT, is supplied to one input port of the microcontroller, which can be sampled by the ADC. The VOLT signal is also supplied to one input of the comparator (172) via resistance (174). Another input of the comparator (172) is connected to a 2.5 VDC level on the node (170) via resistance (176). Thus, the comparator (172) operates as a zero-crossing detector and changes the output power state each time the voltage passes through zero. The comparator output signal, referred to as ZERO, is supplied to the microcontroller as an interrupt signal.

The circuit (180) generates a 25 VDC bias level for the node (170). The resistance (182 and 184) provides a voltage distributor that establishes a voltage midpoint between the ground and the circle before +5 volts. The feedback resistance (186) servos the amplified group output with this voltage.

In the example embodiment of Drawing 26, four channels are shown for measuring current in one branch circuit, respectively. Since the four channels are the same, only one will be explained. The channel (190) will be selected as an example. The current of the branch circuit is detected using a toroidal-core coil (192), such as a Coilcraft CS60-0 current sensor, as a secondary winding of the transformer having a single winding of the branch circuit conductor (194) threaded through the core as its main winding. The current through the branch circuit main winding reduces the voltage on the secondary winding, which for the CS60-0 current sensor is about 8-10 millivolt peak-to-peak per ampere (rms) in the branch circuit, using a 50Q load resistance (196). The amplifier circuit (200) with a computational amplifier (202) and a resistance (204, 206 and 208) supplies a gain factor of about 33. Incidentally, the 2.5 VDC bias from the circuit (180) passes resistance (210) and is added to the output of the computational amplifier (202) to place the output of the amplifier between the range 0 and 5 volts, where 2.5 volts corresponds to a zero current signal. The output signal CURRENT1 is supplied to one ADC input of the microcontroller.

The microcontroller's ADC or ADCs convert the VOLT signal and the four current signals CURRENT1 - CURRENT4 into an 8-bit digital number. These transducers are carried out under the control of the thumbware operating the microcontroller. The conversion of each requires about 40 microseconds. To obtain the voltage, current and power at each of the branch circuits, the controller is interrupted at each power line voltage intersection. A timer is then initiated in the microcontroller and one of the branch circuits is read. At the end of one chassis of the electrical cycle at the power line frequency (i.e., 1/240 second relative to the 60 Hz round line frequency), the current in the same branch circuit is read at all times, as determined by the microcontroller timer, and also the line voltage is read. By specifying the first current as IR, the second current as a "c", and the voltage as V, the power P and the reactive voltage-ampere are calculated as $P=V(IR)$ and $VAR=V(IR)$. With a continuous cycle, the continuous is read the current in the branch circuit, which results in a power output in each of the circuits.

The power level in each branch circuit is accumulated by the microcontroller to determine the energy consumed in each branch circuit (device), both power and energy being maintained to report contacting the device via a CEBus (or equivalent) communication link.

Of course, the method is based on the assumption that non-linear loads are not present on the branch circuit, which is an adjustable assumption for motors, heat and resistive loads, however, such assumptions apply equally to electronic loads such as computers, television sets, etc., when the loads are non-linear, energy and power can be obtained by measuring perhaps 100 or more per cycle of measurement-voltage of a greater number of currents. Of course, this requires an analog-to-digital converter that operates at a higher speed than that in an 87C752 microcontroller, but such an ADC is commercially available. Further, if the 87C752 microcontroller is not at a high enough speed, a higher speed microcontroller may be used, and electrical field engineers and technicians may replace the thin microcontroller for the 87C752 shown in the drawings.

The examples discussed so far are not intended for import purposes. More accurate measurements are required for custom building. This accuracy can be achieved by using a high quality current sensor, such as a Bicon current sensor, and by using a higher resolution ADC than that at 87C752. Incidentally, nonvolatile memory is needed to store energy consumption values.

According to the ISA 60 specification described above, the power monitor shown in Drawing 26 incorporates four analog sensor objects (each channel supplies one object) that conform to the specification. According to the specification, the monitor may be polled by another CEBus node (such as a first microcomputer node) or the other node may request that a state change (i.e., power consumption falling below or rising above a selected level) be immediately reported to the requesting device. Preferably, the microcontroller (152) also immediately reports when the power consumption rises to or falls below a selected threshold or a change of greater than or equal to a selected percentage, such an event may be counted as and the energy consumption calculation may be based on a new power level.

The operation of the power monitor microcontroller (152) is shown as a flow diagram shown in Drawing 27. This flow chart includes three procedures, two of which are interrupt-driven.

The procedure (220) runs continuously except when interrupted. First, it is initialized in the short (221). Next, in step (222), the microcontroller wants a request for a state change of the controlled device or a request for a report on the controlled device. If a request/command for a status change or report is received, the controller responds in step (223), and the control loop returns to the entry in step (222). If such a message is not received, step (222) continues the loop on itself. If the zero intersection point occurs in this received AC carrier signal, an interrupt request is generated as described above and as shown in step (230). To provide services to the interrupt, step (232) is executed. In step (232), a reactive current for one branch circuit (selected by a pointer—see below) is read. A 1 hour cycle (i.e., 90 electrograms) timer is started. The control is then returned to step (236) from the interrupt service. When a time on the timer is up in step (237), it generates an interrupt request that is serviced at step (238). In the above step, The positive phase components of the voltage and current are read in the selected branch circuit. In addition, power is calculated as an implicit or implied time stamp. The pointer is then set to select the next branch circuit at the next zero intersection, which ensures continuous cycling through the branch circuit. Finally, the interrupt service routine returns the control to the procedure (220), which remains the same as when the interrupt request is serviced in step (240).

The power monitor can be applied for load sheeding applications in the same way as the current monitor by adding similar relays not shown.

Three-phase system

In a commercial environment, power distribution systems are often three-phase. This presents any challenge to the need in a system according to the present invention for communicating data and instructions through a power line carrier communication system. One solution is to apply the same PLC signal to all three phases. This only requires receiving data signals for one phase, even if the other is redundant.

However, some facility meters for measuring watt-time consumption in a three-phase system are driven through a transducer. The inductance of the converter may block the PLC signal.

If a single phase (110) bolt line is executed relative to the meter, the sensor circuit of the meter can transmit a reading through this 110 VAC line back to the microcomputer.

Communication Subsystem

As previously described, the first microcomputer is preferably equipped with the ability to have one or more communication subsystems. This capability is preferably achieved by having the first microcomputer with the industry standard bus and various sockets on the bus for receiving circuit boards, cards or modules therein. For example, the bus may conform to ISA, PCI, PCMCIA or other standard specifications. The communication subsystem to be installed at this time may be provided with any communication device that meets the standard. Thus, some possibilities may be designated among potential communication subsystems such as modems (e.g., for wired or wireless use), fiber optic data communication links, and packet transceivers (e.g., for use on a telephone system). Depending on availability, other through-needle devices may be added accordingly. In addition, some communication substrates and cards may be installed in a customer's system. In the objection of allowing the system to communicate with each other via these substrates and cards, the communication service may communicate with each other via the customer's microphone computer, provided that it is properly programmed.

Load Shedding

To shed a load, all it takes is to broadcast commands to a device at a particular address or to any device of a particular priority level or types or levels that turn off to turn off. Because the system has distributed intelligence in the form of programmable microcontrollers in each load control module, the controller can determine if the associated load satisfies the criteria established in the message, and if so, turn the load off. In order to turn off all the shed loads, the selected message may be broadcast via the network. Optionally, the message may be addressed by the first microcomputer to a particular device to be turned off or to which power will be restored. As yet another alternative embodiment, the microcontroller may be programmed to restore power to its associated load after a selected time period unless the shedding request is updated. The latter method is useful for reducing mesh paper traffic on the network, which also protects the receiving failure of the power restoration message. As such, for example, the refrigerator can be prevented from being turned off longer than a preset interval (assuming no power loss). As yet another alternative embodiment, the message initializing the load shedding response may comprise data specifying a time interval at which the load must be shed or automatically reconnected to the mains.

The status flag of the device table may be set to indicate a shed state of the device. If an end load shedding broadcast is received, then for each device on the system, the first microcomputer checks the status flag and generates a command to restore power to the load. The status flag is also changed during a timed event.

If a timed event occurs during a load shedding event initialized by the power facility, setting the flag to a timed event state will prevent the device from turning on by a global termination shedding message.

A suitable flow diagram for the program module (240) to be executed by the first microcomputer is shown in Drawing 28. This program module is for use in a first microcomputer to address a specific local control module implementing load shedding. This can be done frequently (i.e., every time scanning for keyboard input or input from a communication system) because the load shedding cycle can be initialized and terminated in any way, allowing the field to turn on after being turned off. It is also carried out from the program of Drawings 38 and 39 as a last check prior to turning on the load to ensure that the load does not violate an absurd load shedding request, as described below.

This program is entered in the block (242A). This first checks the load shedding status flag (not shown) to determine if the load shedding status has changed since the last time was referenced (step 242B). The load shedding status flag is the content of the specified memory location, wherein the bit is set by the first microcomputer each time a load shedding request (command) is received, and the bit is reset (i.e., cleared) when a message is received ending the load shedding period. In addition, the load shedding status flag includes an amount of bits that record a load shedding priority level that is currently in progress. As such, the content of the load shedding status flag will change at the beginning or end of the load shedding interval, as well as whenever the priority for the shedding changes. If the load shedding status flag has not changed, the control branches to step (242C). In step (242C), the current load at this time is compared to the time when the next scheduled event occurs (preferably, to simplify such comparisons, each day's events in the event table are kept chronologically). If the current time is before the next event to be executed, the program exits (step 242D) and returns it to the program calling control. However, if the current time at this time is the same or later than that of the next event to be executed, the status flag (field) in the DEVICE table is set to show the new condition for the device associated with the event (step 242E). (As such, even if the event is not allowed to occur, as described below, the status flag nevertheless shows the device status as if the event occurred.) Next, the priority level of the device and the load shedding status flag determine whether the event is allowed to run (step 242F). If the event specifies, for example, that the device is to be turned on and that the ongoing shedding request to be violated was the device to be turned on, the event will not run, and the device will not turn on. If the environment does not allow the event to run, the control returns to step (242G). In step (242G), a pointer called an event pointer is updated to point to the next event and the program exits step (242H).

(This event pointer is simply a place in the memory, the content of which addresses the next event in the event table to facilitate identification of the next event, and the use of such pointers is conventional programming techniques.) Assuming that the device priority and load shedding status flag allow for the execution of the event, the control flows from step (242F) to step (242I), and a suitable command is issued to execute the event. Step (242I) comes next, and step (242G) and (242H) are executed as detailed above.

If the load shedding status flag has changed since the last investigation, the control flows from step (242B) to step (244 A). In step (244A), it is determined whether the load shedding priority level has been increased or decreased. If the shedding level is increased, this indicates that further loads will be shed, and the program branches into step (244B). Thus, a pointer, called a shedding pointer, is set to point to the first device of the DEVICE table(s). Next, a series of steps (244C-244F) are executed to check each device in turn, and turn off if the priority level is within the range to be shed. The program then exits step (244G).

If the shedding level is established as reduced in step 244A, instead a series of steps are executed to check each device in the DEVICE table in turn, no longer a shedding request, except for the shedding condition and its program turns on devices that do not follow the established schedule. These steps are shown in 246A-246F. When there are no more devices to check, the program exits step (246G).

Power Outage

In the first microcomputer, the status of the machine is frequently stored, such as every 30 seconds. Not only is the data stored, but the current data and time are also stored. When the first microcomputer is powered up after a power outage, it reads the data and time from the CMOS clock (which is conventionally present in the current microcomputer), and then reads the previous state of the machine together with the data and its recording time. From the two time differences, the outage period is determined and logged for later reporting to the appropriate usage company.

Reporting

The reporting that this system can generate for both customers and power companies is of great use. One is to fully list the reports that may arise from the available information. Data from both the current and power monitors of the system and its data structures can be transferred to conventional database programs that can be reported and investigated in countless bars. However, some reports generated experimentally or in simulation will represent the value of the system.

In Drawing 29, the graph (252) depicts the customer's total energy consumption during a day compared to the graph (254) of the running average of the customer's usage. The horizontal axis is shown in one hour increments. If the customer wants to know the facility that caused the peak at about 3:30 and 4:30 a.m., the graph (not shown) for the individual facility can be duplicated in the graph (252). In this example, the peaks were known to be caused by the operation of the electric garment dryer.

A small peak near 1:30 was caused by vacuum cleaners and furniture lights that were turned on. Another example is shown in Drawing 30, where the bar graph is written to illustrate the cost of operating a monitored load in a household for a week; data like this will vary from state to state and from household to household. The other drawing in Drawing 31 is a bar graph illustrating how much total energy consumption is due to each of the various loads as a function of daily time. Another method of referring to the available data is the report shown in Drawing 32, which will make seasonal changes clear by depicting the bars that each bar represents the daily average cost of the monitored load over a selected time interval, and selecting another interval to report. Seasonal changes may also be observed by selecting for one load (i.e., an aircon), which is a report such as that shown in Drawing 33. The total annual cost of operating each load can be seen as a report as shown in Drawing 34. The reporting generator module includes a spreadsheet program and template that generates each of the reports. However, the user may load any collected data into the spreadsheet program of the user's choice, which then allows the user to inquire about and obtain some type of question. For example, the user determines how much can be saved by next operating a particular facility for different schedules.

Similarly, the total energy consumption is shown, for example, as shown in in Drawing 35 (which represents the result in dollars cost) or Drawing 36 (this shows the result in kwh), a bar graph constituting an energy usage speed indicator is displayed on a monitor of a second microcomputer. In Drawing 35, the box called the current energy load displays the energy cost for the most recent 32 meter reading interval nominally hourly and the corresponding number of kilowatt hours. A sequence of such 32 second interval measurements along the left side of the screen and a length of several flat bars proportional to energy consumption are shown. Optionally, an alarm may sound or the screen color may change as a function of the amount of energy being consumed (As shown in Drawing 37, it shows how much energy, how many hours, over a day, a customer has consumed at a given level, expressed as a fraction equal to the maximum).

Timed conditional action

The flowchart of the first program module for performing the condition on/off device operation is shown in Drawings 38-40 for the program module flowchart to be executed on the microcomputer. These program modules are periodically executed, as well as before turning on the device (a device that should no longer be turned off and thus be controlled is identified as such that the next speed decreases (step 302). Next, if a device type is established in step (340) and the device operation is to be controlled based on total cost or total time, the control branches to the module (306), which is expanded in Drawing 39. However, if the device operation is controlled based on energy speed (i.e., cost per kwh) or total time, the control branches to the module (308) extending in Drawing 40. The modules (306 and 308) are then executed and the next device is returned to the step (310) to be identified. In step (312), a determination is made as to whether all devices have been checked. If not, the device type is determined in step (304), the program runs as described above, and if all devices are not checked, the module exits.

Referring to Drawing 39, it is first checked whether the device is already turned on in step (306A). If not, the current date is compared to the last date allowed for the device to turn on from the memory in step (306B). If the date matches, the module exits the device without turning it on. If the date does not match, the device will be allowed to turn on if this does not violate the ongoing load shedding behavior. As such, a program (240) is called, and if the program (240) allows, a turn-on message is generated, and the usage count for the device is also reset to start recording usage during the usage interval in step (306C). On the other hand, if the field is already on, then the program checks whether the total time has been reached or exceeded (step 306D). If the answer is positive, the device is turned off (step 306F). Similarly, if the total time on-in exceeds what was authorized, then a check is made in step (306F) to determine if the total authorized cost has been reached (step 306F). If the answer is positive, the device turns off (step 306E), and the module exits.

Drawing 40 shows a flow diagram for a module (308). First, we see if the state of the device is checked and is already turned on (step 308A). If the device is on, check to see if the current maximum daily time allocation has been reached (step 308B). If so, the device is turned off (step 308C). If not, a check is performed to determine if the current speed at which the energy was charged exceeds the maximum allowed charge set by the customer to the device (step 308D). If the answer is positive, the device turns off (step 308C), otherwise the module shuts down. If the device is not on (step 308A), the module determines whether the current maximum daily time allowed for the device has been reached (step 308E). If the maximum time is reached, the module exits without turning the device on. However, if the maximum time has not been reached and the ongoing load shedding operation has not been violated, the device is turned on (step 308G) and the current energy speed has not exceeded the maximum permitted speed set by the customer (step 308F), step (308G) integrates the call to the program (240) to perform the load shedding screening operation.

Use and Benefits

Thus, it will be appreciated that the system of the present invention is highly flexible and can be operated in various ways to perform many diverse functions. The following actions and advantages are included at a minimum.

A. Remote Electric Meter Reading - The system provides an interface that allows energy consumption information to be transmitted from the customer's building to the power company. The transmission operation may be initialized by the power company to request information to a microcomputer in a customer's building. Consumption information is updated on a daily and hourly basis to facilitate charging operations that differ from the daily time. The information request may be generic or the information to be exported may specify the contents of a memory address where the watt-hour meter reading is stored. This information can have great value for a facility that can be generated and used to benefit actual customer energy usage profiles. Ancillary advantages include facilitating billing when the property is sold. The seller may be billed up to the selected time (the meter may be read remotely at that time), and the buyer may then be billed. These features can be combined with two main points:

B. Remote Access and Disconnection - By providing remote monitoring and load shedding commands using the system, the power company may supply the customer with energy on a prepaid basis (see below). If the power company finds that the customer has exceeded the advance payment or has exhausted the credit amount, the service to the customer will be disconnected remotely (or will be reconnected later). For this purpose, a remotely adjustable watt-time meter switch is already available, and the present invention facilitates the operation of such a meter, even if it enables the use of a CEBus meter rather than a meter controlled by a wireless signal. For example, because usage is being monitored through the first microcomputer, it may be programmed to drive the meter switch (via a suitable interface) at a preset time or in a preset state (i.e., the amount of energy consumed). Remotely adjustable and watt-time meters according to CEBus may be obtained from, for example, Landis Gyr. The facility may remotely check that the meter switch was driven to de-energize by integrating the first microcomputer with respect to the meter reading the amount of time. If the meter scale does not change, the power will be shorted.

C. Revenue Protection Alert - In order for the base computer to be in customer building monitoring power consumption and to control the installation and power emergency during peak usage time (energy costs typically increase at any time), the system in the present invention provides the power company with a revenue protection feature. First, when the customer moves, the system can be used to read the meter, allowing the company to issue a final bill to the customer. Second, it notifies the system of the customer's building so that remote separation can be performed as described immediately above. Even if the building is not equipped with remote separation features or if the remote separation features are not driven, the degree of protection against unauthorized power consumption can be achieved, and the system of the present invention can be used to monitor customer usage to ensure that all major facilities are turned off and no significant power is consumed. This is done by reading the watt-hour meter on a periodic basis (i.e., in daily or even numbered hours). The first microcomputer in the building may be programmed to perform this automatically, and the power company may also issue a remote request for meter information. If the system is using power, it may transfer the notification to the power company and the power company may take appropriate action. Incidentally, the system monitors the power company or allows the power company to monitor a particular facility to ensure that the customer does not consume power during a specified (i.e., peak rate) cycle if the customer has agreed not to use the facility under such conditions.

D. Emergency load shedding - During an emergency throughout the region, in order to improve power system readability and distributed control system load, the customer may prioritize the load and the power company may be allowed to deliver a message to short circuit the load to a selected priority or priority sequence (to both individual customers such as those in a particular region and a group of customers). For example, the customer may be allowed to prioritize loads from Level 0 to Level 3. A customer may designate a priority 0 facility where power is rarely interrupted, two priority 1 facilities where only power will be interrupted in order to avoid a rolling blackout, any number of priority 2 facilities that will be cycled on or off to maintain system stability in an emergency, and any number of priority 3 facilities that are deemed not essential and can be shed at any time by the power company. Such a method allows the power circuit to reduce peaks and to avoid the need for power use to help build ancillary generating capability or reduce energy speeds. Further, while reducing the risk of rolling blackouts in extreme conditions, it sets its own priorities for load shedding and provides the power provider with the degree of freedom to control over the system load.

Incidentally, the customer may continue to be notified of such conditions through the display of the second microcomputer in the customer's building. In order to reduce the message traffic, as a result of the absence of power at any named facility, the same message that performs load shedding invokes a display message indicating that a need has risen for shedding load at the customer premises.

E. Power Outage Notification - The system may also provide a power outage notification feature, which informs the power company when a power outage condition is present in the customer building. This feature can be implemented in a variety of ways. According to one selection, the microprocessor of the first microcomputer may integrally circuit the interrupt request serviced by a routine that detects the power supply voltage is dropped and sends a message indicating that the power failure occurred at that location. According to another option, if the microprocessor does not incorporate such a circuit, it may be individually supplied and connected to the microprocessor to supply the interrupt request signal. The outage message may be transmitted to the power company via a telephone system or RF (wireless) broadcast or other channel. If the telephone system will be used, the CPEU must include a telephone dialer (not shown) or a communication program and modem (not shown). If an RF transmission is to be sent, the CPEU must have an RF transmitter and program to control the entire transmission and broadcast the message. Preferably, an auxiliary power source (such as a battery or capacitor, not shown) is provided to the CPEU to ensure that sufficient power is present for the time sufficient to send the outage message. The use of RF broadcasting is preferred over the use of telephone messages to increase the similarity of messages being received by the power company, and when a telephone signaling system is utilized, factors of power outage (e.g., strong trees across power lines or lowered power bars) may cause another telephone service outage. By comparing outage notifications from countless customers, the power company instructs the repairer to detect the location and repair the problem location at a new and low cost, since the repairer cannot waste time detecting the failure.

F. Local emergency alarm - Using the same messaging service used for load shedding, local alarm characteristics may be provided. This allows the power company or its designee to broadcast to the customer selected local news and alarm messages (for this purpose of the display) related to emergency situations such as service weather warnings. If an audible alarm signal is issued by the customer computer, it can be broadcast and a special alarm message can also be displayed on the computer screen. If the interface is installed between the system and the customer's television or cable television system, the message may be automatically turned on and adjusted to a special energy channel for search and display of detailed information and sent to update as they are broadcast.

G. Invoice Payment - Using the communication capabilities of the system, the customer can display his/her/its account information on the screen and authorize payment by electronic cash transfer or credit card. This could reduce direct labor and mail costs for power companies.

H. Interrupt Analysis - The main source of service calls to electronic power companies is a temporary interruption of service. Such interruptions are often caused by the tree rim contact overload line, causing the [sic]boch relay to operate. These interrupts often irritate customers who need to reset their digital clocks and other equipment as a result of the interrupt. Interrupts of this kind are a stand-out call for compliant calls to the power company, and handling these calls is costly. By tracking a momentary outage in a customer's building, the system allows for accurate detection of the location of such a line contact and enables active correction of an effective cost of the condition. In particular, if the first microcomputer detects a number of momentary interrupt meetings and a period of time established by the power company, this may initialize the message to the power company, requesting a service call by the line worker. By determining whether a similar request was received from another customer's CPEU, the power company may detect the problem and instruct the repairer to go to the problem area.

I. Customer Control Circuit - Through the system video interface, the customer can control the lights and equipment. For example, a customer may operate an exterior or interior of a light, start a coffee pot, operate a sprinkler system, schedule a full pump, etc. All such operations can be controlled from a central location using a video interface that presents an input/output display designed for the type of load.

J. Temperature control - Via the video display, the CEBus-compatible thermostat can be programmed to a selected comfort level for each day of the week and the hour of the day.

K. Seasonal mode - With this selection, the customer can store lights, heating and cooling schedules in a seasonal manner.

L. Empty Nest Mode - This option enables customers to save schedules for energy usage that reduces power consumption while on vacation and when away from home. Combined with a humidity sensor, it allows the dehumidifier or air conditioner to be switched to reduce the risk of mildew during periods of high humidity.

M. Power Pickup Staging - When a power failure occurs, a message may be delivered to all control modules by the first microcomputer to open all breakers and short the load from the main power source before the backup control power is lost. Optionally, the breaker can short-circuit the energy supply at the open circuit location and close it until it is signed to do so without re-energizing. When power is restored, the first microcomputer connects each load to a line in a sequence selected based on the type of equipment and its initiation requirements. A four relay within the selected range may also be added to avoid on-line all equipment of any kind at the same time. This capability ensures that all such loads are restored to instantaneous power and do not return to the on-line where its energy resupply is hindered. This helps to reduce the high stress on the power system and minimizes the difficult load pick-up problems. Incidentally, some installations require a reset cycle before power is restored, which later includes an air conditioning system. The programmed latency allows such a facility to return to the normal on-line, and initiates too soon to avoid stress on the power system and the facility.

N. Cost Savings - The present invention has certain advantages in favor of cost to the customer. The watt-time meter and the first microcomputer are part of the CPEU that exists outside the customer building and is owned by the power company. Therefore, customers do not need to invest in these items. The client's investment is limited to the second microcomputer and various load control modules. As load control modules are included in new facilities during manufacturing, there will be no need to invest individually in such facilities, etc. Therefore, the client's investment is kept to the utmost. In addition, since the power company has control through the CPEU, the device may be increased as needed and the computing and control capabilities of the first microcomputer may be used, as selected. This includes adding a communication substrate that interconnects the PLC of the building with various other communication services. Thus, if a CEBus node can be used to convert a CEBus message to a conventional television signal for displaying it on a television, a card is added to the CPEU to enable other services to deliver a message for display on the customer's television. In addition, the CPEU may have a substrate that enables the message to be delivered to a customer via a selected medium (i.e., via a cable television distribution system, telephone or RF link) to another service provider, such as a cable television company (i.e., order service, reporting issues or questions, etc.).

In addition, by using the first microcomputer as a server that provides computing, communication, or other support for the device that the customer purchases, other cost advantages go back to both the customer and the power company. The cost of the device is reduced by not providing the capability given by the system, and the power company can change the manufacturer for providing access to the first microcomputer. The manufacturer can also be replaced to communicate with the device via CPEU.

There are incidental cost advantages that power company services other than power can be quantified through this system. It is known that there is a significant cost associated with dispatching agents to customer buildings to read gas, water and electrical meters. These meters can now be interfaced by this system to CEBus or other PLC or network communication systems for remote reading, greatly reducing the cost of reading meters.

O. Energy Isolation - The present invention also facilitates the implementation of a system that enables real-time energy sourcing markets or shutdowns. Various electrical energy providers can supply their speed structure to potential customers, which is often practiced when it is desirable to change speed more often than per hour. By using a second microcomputer as a communication terminal, customers can receive these disclosures if they are supplied electronically and then act as distributors to new suppliers for any future time interval. The customer's power cycler acts as a distributor to the available supplier. When a customer changes a supplier, the power company crawls the initial supplier account for usage at the initial supplier speed to obtain a remote meter scale from the customer's meter, record the speed to be charged by the new supplier to the customer's system, and record the new customer-supplier relationship, its start date and time. Each supplier determines a minimum commitment within prescribed limits and contracts for that service, and the utility's computer systems are properly programmed so that customers can only switch suppliers in accordance with the minimum commitment and other contractual terms. Thus, the energy provider enables the customer's work to be completed. Of course, the power company may be a supplier and a distributor if allowed by regulatory law. Thus, the present invention enables perfection of the energy market at the end user level.

P. The ease of smart equipment – and incidentally, the system according to the present invention facilitates the development and use of so-called smart equipment. For example, recipes can be downloaded directly through the CPEU from a source outside the customer building (i.e., a power company or connected service) to the microprocessor-control oven. At this time, the customer does not have to worry about programming the oven for the correct temperature(s) and time(s). In another embodiment, the CEBus facility may automatically call the manufacturer for the service if internal diagnostics indicate that a problem exists. This can be placed via telephone or via the power company's computer system if a telephone interface or modem is provided to the CPEU. The CPEU may store programming information for the facility and, when power is restored after a power outage, the CPEU and the facility may interact to restore programming for the facility (i.e., VCR programming) and reset the clock of the facility.

As used in the present invention, the terms energy and power can be used interchangeably except that one is intended to exclude the other.

Of course, energy is the time integral of power. As such, the energy used by the load over a predetermined time period is calculated by measuring the power input to the load through the number of samples taken over a continuous instantaneous time period in the present invention. Nevertheless, according to each country, inventors often uses the example of measured energy or consumed energy, in which the energy is calculated from the measured quantity and the energy is actually converted from an electrical form into another form (ie light, heat or motion). If energy is used where the power is more accurate, or vice versa, it can be seen that the more accurate term is intended to be used.

While various embodiments of the present invention have been described as such, it will be appreciated that some of the advantages and optional features thereof have been expressed as such embodiments are merely exemplary and not intended to be limiting. Those skilled in the art will appreciate that there may be a variety of modifications and modifications to both the incidental embodiments as well as those embodiments without departing from the nature and area of the present invention. For example, although it is shown that the load control module is separate from the controlled load, it will be appreciated that the facility may be designed with the control module as its integral part. Indeed, it can be seen that so-called future smart facilities can be built, for example, with embedded circuit breakers and/or power monitoring circuitry as well as CEBus or other interfaces provided. In another variation, instead of using an industry standard microcomputer platform for both the first and second microcomputers, one or two microcomputers or their operating systems may be non-standard, and some flexibility will be lost, but in other words, one or two processors can be replaced with a non-programmable controller, which can also be dedicated hardware. Accordingly, the present invention is not limited to the scope and equivalent of the following claims.

(57) Scope of Claim**Claim 1**

A first microcomputer for use in conjunction with a second microcomputer for controlling the operation of a plurality of injector loads in a customer building, comprising:

means for receiving a message comprising a request to implement a load shedding operation (load shedding operations) at the customer building via a communication link and supplying the first microcomputer;

means for receiving a command scheduling an event associated with an operation of a load from the second microcomputer;

means for collecting and storing data describing historical power (or energy usage by a customer); and

a means for transmitting the load shedding operation and a message executing the scheduled event to the load control module.

Claim 2

The method of claim 1, further comprising:

a watt-time meter quantifying energy consumption in the building and a means for reading historical data comprising data obtained by reading the watt-time meter.

Claim 3

The method of claim 1, further comprising:

further providing a means for monitoring and measuring the consumption of energy by the at least one load device.

Claim 4

The method of claim 1, further comprising:

the first microcomputer further comprising a data structure, the first microcomputer periodically executing operations of storing energy consumption measurements of each of the devices in the data structure.

Claim 5

A secondary control group for controlling the operation of multiple electrical loads in a customer building, the auxiliary control group for use with a master controller, the auxiliary control group comprising:

means for communicating with the master controller;

means for displaying a message to the customer;

means for obtaining historical energy consumption data for one or more loads from the master controller; and

in response to the request, providing a means for generating a report describing the historical energy consumption on the display means.

Claim 6

The method of claim 5, further comprising:

wherein the generating means is characterized by generating a graphical indication of the rate at which energy is being consumed in the building on the display means.

Claim 7

The method of claim 5, further comprising:

wherein the generating means is characterized by generating a graphical representation of the rate at which the selected load device is consuming energy on the display.

Claim 8

A system for connecting an electrical load to a main power source at a selected time and controlling operation of the load to separate the electrical load from the mains power source, comprising:

a. a first microcomputer having a first processor connected to communicate with each other and a first memory, and a first control program controlling the execution of operations by the first microcomputer;

b. a second microcomputer provided with a second processor and a second memory connected to communicate with each other, and a user means for a user providing input data and a second control program controlling execution of the same by the second microcomputer;

c. at least one local control module comprising at least one command to control a state of a load in response to instructions from the first microcomputer, and to connect the load to a mains power source and separate the load from the mains power source; and

- d. a communication channel,
- e. both the first and second microcomputers and the load control module are adapted to communicate with each other via a communication channel, such that the first microcomputer transmits instructions to the load control module via the communication channel, and
- f. in response to input data provided to the second microcomputer by a user, the first computer program causes the first microcomputer to execute commands in a database of load events to be generated embedded in the first memory at a selected time; and
- g. wherein the first microcomputer executes instructions in the first computer program to obtain the load event from the database at a selected time, and executes corresponding instructions to transfer instructions to the load control module to connect a load to a mains power source or to separate a load from the main power source.

Claim 9

The method of claim 8, further comprising:

the channel is a power line carrier communication channel established via the main power source.

The method of claim 8 or 9, further comprising:

Claim 10

wherein the second microcomputer also comprises a database of load events occurring at a selected time, and wherein the second computer program and the first computer program are characterized in that the second microcomputer interactively executes each time the second microcomputer is turned on to synchronize the contents of the database in the second microcomputer with the database in the first microcomputer.

Claim 11

The method of claim 10, further comprising:

wherein the first and second computer programs are turned off to synchronize the contents of the database at the second microcomputer with the database at the first microcomputer, and then interactively run when the second microcomputer is first turned on.

Claim 12

The method of claim 10, further comprising:

during a successive selected interval, further provided with an electrical energy consumption metering subsystem for quantifying electrical energy consumed by a load connected to a mains power supply and supplying a value of the metered energy, the first microcomputer operating to obtain the metered value indexed in the successive interval from the metering subsystem and store the metered value in the database of the first microcomputer,

wherein the second microcomputer is operated over time to transmit a request for a selected number of the metered values to the first microcomputer when turned on, the first microcomputer being operated to transmit to the first microcomputer any of the selected numbers of the metered values not previously sent to the second microcomputer, in response to receiving the request, the second microcomputer modifying the database by adding an entry corresponding to the metered value.

Claim 13

The method of claim 12, further comprising:

at least one load control module is at least one load control module of a kind measuring an electrical usage parameter of a corresponding load, the first microcomputer being adapted to receive a message comprising the measurement from the load control module via a communication channel, the first microcomputer operating to store the measurement in the first database in a manner that associates the measurement with the corresponding load.

Claim 14

The method of claim 12, further comprising:

at least one load control module is adapted to measure a voltage across a corresponding controlled load, a current passing through the load, and a phase angle of the current relative to the phase voltage.

Claim 15

The method of claim 14, further comprising:

a means for calculating energy consumption of a controlled device and a power factor for the device.

Claim 16

The method of claim 15, further comprising:

wherein the calculation means is located in the load control module.

Claim 17

The method of claim 13, further comprising:

wherein the residing second microcomputer is operable to request the measurement from the first microcomputer, the first microcomputer being operable by transmitting the measurement to the upper limb second microcomputer in response to the request, wherein the second microcomputer stores the measurement in the second database in association with a corresponding load.

Claim 18

The method of claim 13, further comprising:

wherein the first microcomputer may store a selected first number of daily metered values and a selected first number of load measurements, and wherein the second microcomputer may fail a selected second number of daily metered values and a selected second number of load measurements, and wherein the first and second computer programs interactively execute on the first and second microcomputers, respectively, when the second microcomputer becomes active after being inactive, such that the contents of the weighed values in the second microcomputer and the database of sub-measures are transmitted to synchronize the databeth of the weighed values and load measurements in the first microcomputer.

Claim 19

The method of claim 18, further comprising:

wherein the first and second programs interactively execute to synchronize the contents of the database to the second microcomputer during a time period after power has been de-energized.

Claim 20

The method of claim 18, further comprising:

wherein the first and second programs interactively execute to synchronize the contents of the database to the second microcomputer for a first time after power is turned on.

Claim 21

System according to claim 18, characterized in that the database in the second microcomputer is capable of storing more metered values or load measurements than the database in the first microcomputer.

Claim 22

A system for controlling operation of at least one electrical load field that selectively separates each load from a mains power source or enables the load to be connected to the mains power source in response to a load shedding command signal received from an electrical energy provider, comprising:

- a. a first microcomputer comprising a first processor and a first memory connected to communicate with each other, and a first control program for execution of operations by the first microcomputer;
- b. means for receiving the load shedding command signal from a power company;
- c. at least one load control module comprising at least one instruction to control a state of a load in response to instructions from the first microcomputer, and to connect the load to and disconnect the load from the main power source; and
- d. a communication channel,
- e. the first microcomputer and the load control module are adapted to communicate with the other through the communication channel, such that the first microcomputer communicates instructions to the load control module through the communication channel;
- f. wherein the first control program is characterized in response to receiving a load shedding command signal by the receiving means, causing the first microcomputer to carry out instructions to carry out an operation of the load control module corresponding to the command to at least one load control module.

Claim 23

The method of claim 22, further comprising:

wherein the receiving means lies with the first microcomputer.

Claim 24

The method of claim 22, further comprising:

Each load control module is associated with a load device, each load device being assigned a load shedding priority among a defined set of possible load shedding priorities, and each load shedding command from an electrical energy provider comprises within it a specification of the priority level at which the command operates, the system comprising:

- g. a data structure comprising a first microcomputer with its assigned load shedding priority for each of the load devices,
- h. wherein the first computer program is characterized in response to the assigned load sharing priority in the data structure by operating the first microcomputer such that the priority level conveys a load sharing command to a load control module for a load corresponding to the priority level or the level at which the load sharing command operates.

Claim 25

The method of claim 13, further comprising:

wherein the first microcomputer also comprises a data structure comprising a list of load events occurring at a selected time for each load, and wherein the first computer program is characterized in that it operates the first microcomputer to execute an operation of the load control module implementing the event except when the execution of any of the events in the event is inconsistent with a previously issued load shedding instruction.

Claim 26

The method of claim 22, further comprising:

g. a data zoning comprising, for each load control module in the first memory of the first microcomputer, at least one device type identifier for a sub-device controlled by the module, an identification for the module, and a load shedding priority assigned to the load device selected from a defined set of possible load shedding priorities,

h. wherein the first computer program is characterized in response to receiving a load shedding command from an electrical energy provider, controlling the operation of the first microcomputer to send a load shedding instruction only to such load control module in accordance with the specification in the load shedding command for the load operated by the associated device type identifier, the identification for the module and the assigned load shedding priority for the load device.

Claim 27

The method of any one of claims 22 to 26, further comprising:

wherein the load control module is adapted to separate its associated load from a mains power in the event of a power failure to the mains power, and wherein the system further is provided with means for directing the load control module to allow reconnection of the associated load to the mains power after the end of the power failure.

Claim 28

The method of claim 27, further comprising:

wherein the means for directing the load control module communicates instructions to allow the reconnection at a selected time after the end of the power failure to the module, and wherein different selected times are used in different load control modules associated with different kinds of load devices.

Claim 29

The method of claim 27, further comprising:

the means for commanding the load control modules transmits instructions that allow the reconnection to the modules after a pseudorandom (pseudorandom) time from the end of a power failure.

Claim 30

The method of claim 29, further comprising:

the time of the pseudo random number is variable for each of the load control modules.

Claim 31

A monitor for remotely determining a current state of a power supplying a power supply to an electrical load, the monitor comprising:

- a. a winding wire pierced by the branch circuit constituting a primary transformer to constitute a secondary transformer;
- b. a first means for determining whether an output of the winding wire exceeds a predetermined first threshold; and
- c. a first means for the determination and means for interfacing a communication channel that is a passage for providing a mesh paper indicating a current state of the branch circuit in comparison to the threshold.

Claim 32

The method of claim 31, further comprising:

a second means for determining whether the output of the windings exceeds a predetermined second threshold, the interfacing means comprising a second means for determining and a means for interfacing the communication channel.

Claim 33

a monitor for determining parameters related to electrical energy consumption by the electrical load on a semi-term circuit provided with a branch circuit conductor supplying an alternating current (ac) to an electrical load and applying an alternating voltage to the load phase,

- a. means for determining a current in the branch circuit at a zero-crossing point (zero-crossings) of an alternating voltage applied to the load phase;
- b. means for determining a current in the branch circuit after 90 degrees electrically from the zero-cross point; and
- c. means for calculating the nudge consumption of at least one by the load using a value multiplied by the voltage of at least one of the currents.

Claim 34

The method of claim 33, further comprising:

means for measuring the voltage across the load.

Claim 35

A method of controlling the restoration of loads for a power distribution system tracking the occurrence of a power outage, the method comprising:

- a. supplying, for each of the loads, a related sub-control module for controlling a connection between the power distribution system and the load; and
- b. transmitting, to each module, instructions for reconnecting the associated load to the power distribution system in a predetermined procedure when power is restored.

Claim 36

The method of claim 35, further comprising:

- c. supplying backup power capable of supplying electrical backup control power for a short time after a power failure; and
- d. sending, in the event of a power outage, a message to all control modules for blocking the loads from the power distribution system before the backup control power is lost.

Claim 37

The method of claim 35, further comprising:

wherein the predetermined procedure is based on the idle and restart conditions of the load.

Claim 38

The method of claim 35 or 37, further comprising:

transmitting a reconnect command to each of the modules performs a reconnect after a pseudo-random time from a power restore.

Claim 39

A method for performing a preventive maintenance on a power distribution system for an electrical energy provider comprising a plurality of cables supplying power to a plurality of customer premises, wherein the cable may be subjected to a momentary power outage due to natural and non-natural causes affecting the cables, comprising:

- a. monitoring the presence of a power signal of a power cable at each of the customer premises;
- b. measuring an elapsed time of a monitored power outage on the cable;
- c. notifying an energy provider of the time of the power failure and the occurrence of the power failure, concurrent with restarting the power supply to the cable after a power failure.

Claim 40

The method of claim 39, further comprising:

transmitting a clock reset command to reset a clock in a load of a customer building.

Claim 41

The method of claim 39, further comprising:

- d. using the communication to localize the cables that have been interrupted and to rush staff to resolve the cause of the interruption.

Claim 42

The method of claim 1, 8 or 22, further comprising:

The first microcomputer comprises:

- a. a clock;
- b. a number for recording a time set by the clock when the power transfer is interrupted over a related mains power source;
- c. means operating at the end of the interruption to determine the elapsed time;
- d. automatically reporting the time the interruption occurred and the elapsed time thereon.

Claim 43

A system for controlling operation of an electrical load device for connecting and disconnecting a load from a main power source under certain conditions, comprising:

- a. a first microcomputer having a first processor and a first memory connected to communicate with each other, and a first control program for controlling operation execution by the first microcomputer;
- b. a second microcomputer having a second processor and a second memory connected to communicate with each other, a user means for allowing the user to provide input data, and a second control program for controlling operation execution by the second microcomputer;
- c. at least one load control module comprising instructions for controlling conditions of a load in response to instructions from the first microcomputer and for suspending the load to a mains power source and separating the load from the mains power source;
- d. a communication channel;
- e. the first and second microcomputers and the load control module configured to communicate with each other through a communication channel such that the first microcomputer may transmit commands to the load control module through a communication channel;
- f. a first computer program that causes the first microcomputer to execute instructions to build an iteratorbase in the first memory in response to input data provided by a user to the second microcomputer, at least for a specific load, the user-supplied maximum speed at which the user wishes to pay for energy to operate the load;
- g. means of receiving an energy rate charge for operation of a load from a utilization company; and
- h. a first microcomputer executing instructions with the first computer program to obtain the user-feed maximum speed from the database, compare the maximum speed to the rate charge received from an electrical energy provider, and transmit instructions to the load control module for distributing a load from a main power source if the received speed exceeds the maximum speed.

Claim 44

A method for providing information to a customer's building about the use of electrical energy provided from an external source, comprising:

- a. metering electrical energy used in a building to calculate an energy consumption meter scale indication;
- b. storing a meter graduation indication in memory at predetermined intervals;
- c. measuring power consumption by each of multiple load devices in a building at predetermined intervals;
- d. storing, in association with each of the load devices, power consumption measurements for them in the memory;
- e. relating information identifying a load device to the memory for each load device; and
- f. providing a report detailing electrical energy consumed by each of the load devices and electrical energy consumed throughout the building as a function of time.

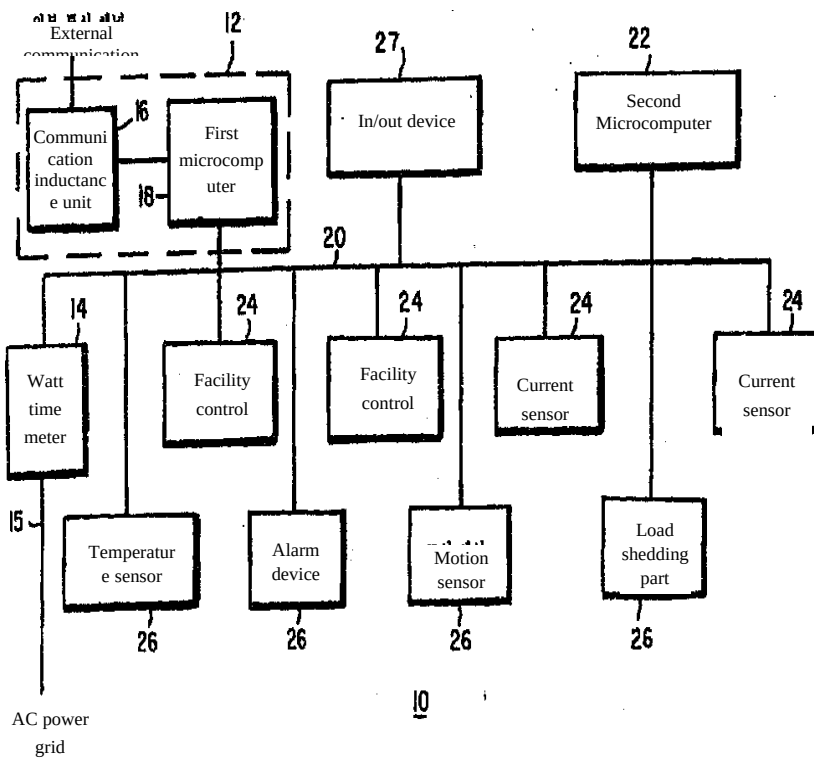
Claim 45

The method of claim 44, further comprising:

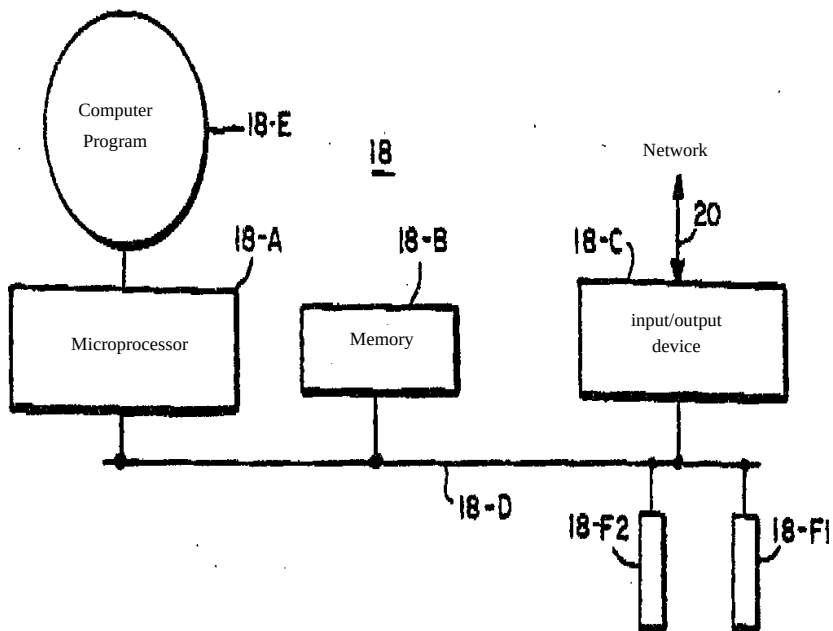
declining the rate associated with each of the types of devices as a function of time in relation to different types of load devices.

Drawings

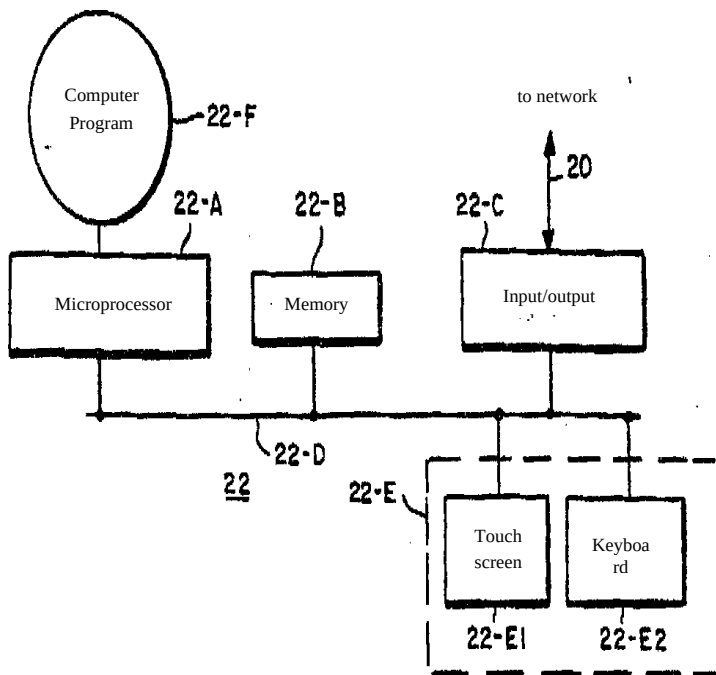
Drawing 1



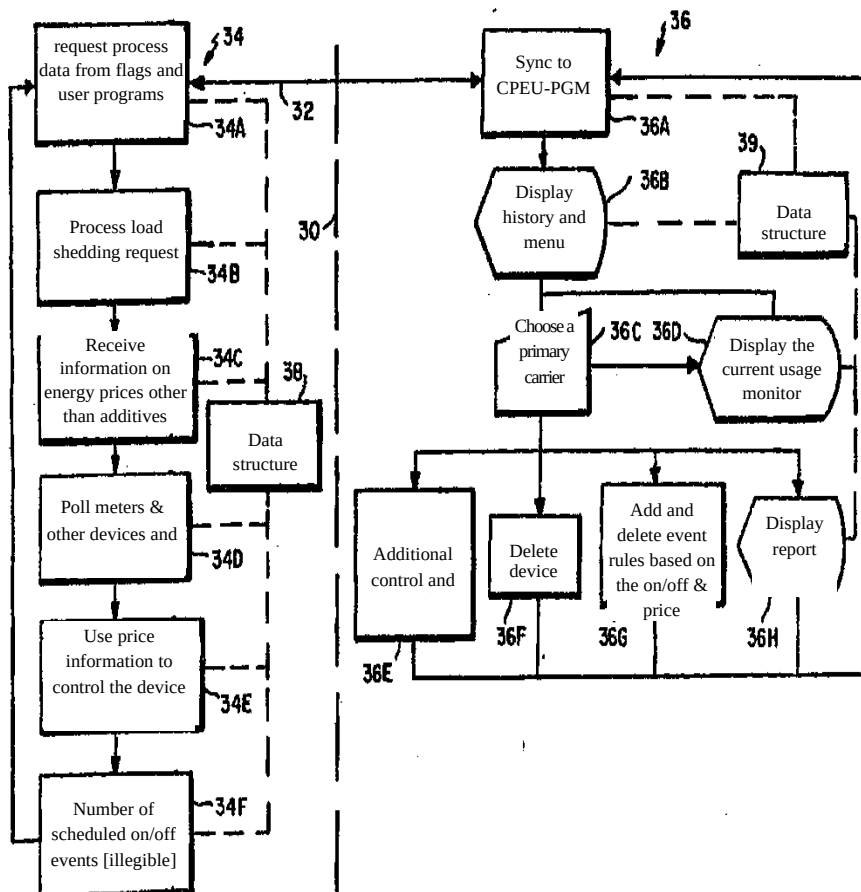
Drawing 2



Drawing 3



Drawing 4



Drawing 5

```

struct CUSTOMER
{
    double cost_kwh; // 42A per kilowatt-hour electricity
                        // 42B usage
                        // Customer Cost
    char name[21]; // 42C Customer
                        // Name
    char addr[31]; // 42D Customer
                        // Address
    char acct[21]; // Customer
                        // Account
};

```

Drawing 6a

```

struct DEVICE
{
    unsigned short watts; // 44A // When only the on/off state is available
                        // Used to calculate POWER usage rate.
                        // Use this device with Watts is [unintelligible]
    unsigned short amps; // 44B // Use this device when AMPS is
                        // [unintelligible].
                        // When only off/on statues are available
                        // Used to calculate POWER usage
    unsigned char volts; // 44C // Use this device when it is VOLTS [unintelligible].
                        // When only off/on is available
                        // Used to calculate power usage.
    unsigned char power_factor; // 44D // Power factor for this device
                        // (Power factor = W/VA
                        //  $W = \text{Watts}$ 
                        //  $VA = \text{Volt} \cdot \text{Amps}$ )
                        // Note: In an alternative current circuit,
                        // the current must match the voltage in
                        // phase. In fact, the product of volts and
                        // amperes must [unintelligible], 1E.
                        // Typical power factor for electric motors
                        // is 8 (Watts x Voltage x 80% of 알파어).
    unsigned char load_type; // 44E // Resistance, induction, floor sensor
    unsigned char priority; // 44F // Priority ; 0 = Not externally controlled by power company
                        // 1 = The most critical state to be dumped off during load
                        // shedding
                        // 2 = Medium priority
                        // 3 = Device in the first neutral queue to be turned off for
                        // load shedding requests, etc.

    unsigned char circuit; // 44G // Not Used
    unsigned char code_number; // 44H // X10 address - number
    unsigned char code_letter; // 44I // X10 Address - letters
    unsigned int cebus_hc; // 44J // CEBus furniture code
    unsigned int cebus_unit; // CEBus unit number
    char desc [13]; // 44K // Description (Filed Information)
};

```

Drawing 6b

```

char location [18]; // 44L // Location (Filed
// Information)
unsigned char status; // 44M // Current Off/On Status
unsigned int current_hours [24]; // 44N // Current device being counted
// Each "Tick" is active.
// Represents 30 seconds
// 44O
unsigned int mtd_hours [24]; // 44O // The starting month of the device
// being counted
// Each "Tick" is active
// Represents 30 seconds
// 44P
unsigned int last_month [24]; // 44P // The final month device being counted
// Each "Tick" is active.
// Represents 30 seconds
// 44Q
unsigned int ytd_hours [24]; // 44Q // The starting year of the device being
// counted
// Each "Tick" is active.
// Represents 30 seconds
// 44R
char cibus_noack; // 44R // If CEBus device, from this device
// Whether or not ACK is expected
// Flag to designate

};

struct DEVICE

```

Drawing 7

48

```

struct COMMERCIAL
{
    unsigned short    com - yr; 49A    // Year of this
                                   period
    unsigned short    com - mo; 49B    // Month of this
                                   period
    unsigned short    com - da; 49C    // The day of the
                                   month of this period
    unsigned short    com - hr; 49D    // Time, this period
    unsigned short    com - qtr; 49E    // Overtime period

    unsigned short    com - id; 49F    // If there are multiple
                                   meters - Meter ID

    unsigned short    com - interval; 49G // Duration Size
                                   (minutes)
    double            com - kwh; 49H    // kwh consumed during this
                                   period
    double            com - kvah; 49I    // kvah consumed during this
                                   period
    double            com - kvarh; 49J    // kvah consumed during this
                                   period

    double            com - demand; 49K // Requires this period
                                   rate
    double            com - min; 49L    // No minute device was present
                                   during this period

    double            com - mtr; 49M    // Meter reading at the end
                                   of the period

    double            com - inter; 49N // Duration Length
};

```

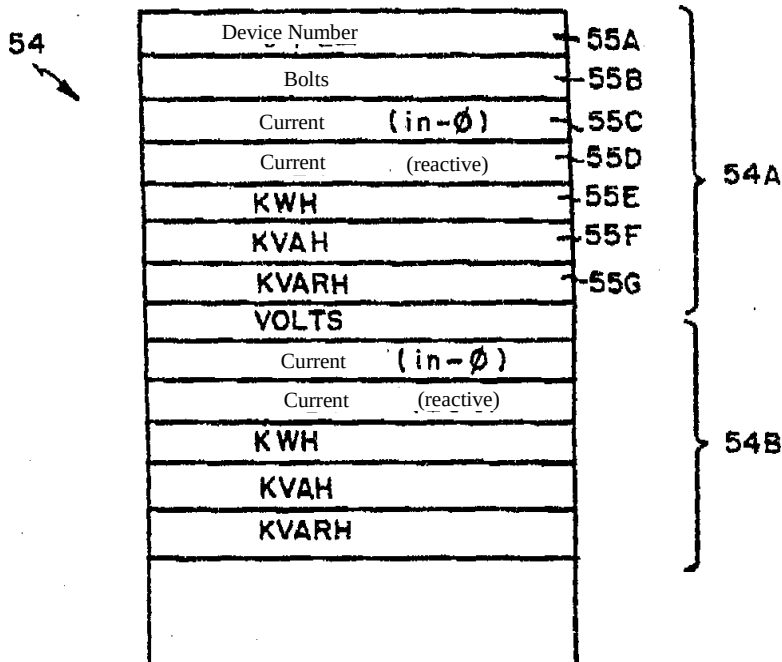
Drawing 8

```

struct METER
{
    unsigned int cebus_hc;           // 53A // CEBus House Code
    unsigned int cebus_unit;        // 53B // CEBus Unit Code (MAC address)
    double current;                 // 53C // Recorded Last Read
    double current_start [24];      // 53D // 1st reading of the time period
                                     // 53E // 24-hour table (1 entry per hour)
    double current_reading [24];    // // Final reading in the time period
                                     // // 24-hour table (1 entry every hour)
    double mtd [24];               // 53F // During this time (does not include today)
                                     // // 24-hour table of energy usage (1 entry per
                                     // // hour)
    double last_month;             // 53G // Energy within the corresponding time
                                     // // period for the final month
    double ytd [24];               // 53H // 24-hour table of usage (1 entry per hour)
                                     // // Energy during that hour for all of the
                                     // // year
                                     // // (not including today)
                                     // // 24-hour table of usage (1 entry per
                                     // // hour)
}

```

Drawing 9



Drawing 10

```

#define MAX_EVENTS 128

struct event
{
    unsigned char device;    // Device on which the event
                             // works
    unsigned char hour;     // Time to Onset (0 - 23)
    unsigned char min;      // Minutes to Onset (0 -
                             // 59)
    unsigned char type_day; // Weekdays during onset
                             // Bit0 = Sunday bit 1 = Monday.
                             // If the bit is set,
                             // this event occurred on that day
                             //
    unsigned char action;    // Conduct: 0 = Off
                             // 1 = On
                             // 2 + 16 • Dim amount = Dim
};

struct event events [MAX_EVENTS];

```

Drawing 11

62

Date: WED. 12/14/94	Time: 02:10:58 PM	Total energy used today 6.0800 KWH \$0.49	Current Energy Load
Add Device	Delete device	Event schedule	Location [illegible]
Marked with [illegible]	Vertical price input	Return	

Drawing 12

Date: WED. 12/14/94	Time: 02:12:13 PM	Total energy used today 6.0800 KWH \$0.49	Current Energy Load
------------------------	----------------------	--	---------------------

Description: Text device
Location: Kitchen
Priority 0
Type of load: N

Watts: 0
Volts: 0
Amps: 0.0
Load Type: Resistive

X10/CEBus X10
X10 A
X10 number:

Drawing 13

Date: WED: 12/14/04	Time: 02:13:39 PM	Total energy used today 6.0900 KWH \$0.49	Current Energy Load
-------------------------------	-----------------------------	---	---------------------

Description	Location	Pri	Mn?	Watts	Volt	Amps	Tp	Address
Air conditioning	[illegible] space	0						CEB...0001-0002
On	Conditioning							
On	1:30a							SMTWTFS
On	1:31a							SMTWTFS
On	1:32a							SMTWTFS
Off	7:00a							SMTWTFS

Time:

12:00
OK
Delete

AM/PM: A

Action: Off

Days: SMTWTFS

Drawing 14

Date: WED. 12/14/94	Time: 02:12:50 PM	Total energy used today 6.0900 KWH \$0.49	Current Energy Load
-------------------------------	-----------------------------	---	------------------------

Blind	Location	Pri	Min?	Watts	Volts	Amps	Tp	Address
Air gun	[illegible] space	0						CER: 0001-0002
Lighting	Hallway	0						X10: A 4
[illegible]	North	0						X10: C 2
Lighting	Living room	0						X10: A 2

<Enter> Delete
e

<Esc> Return
rn

Drawing 15

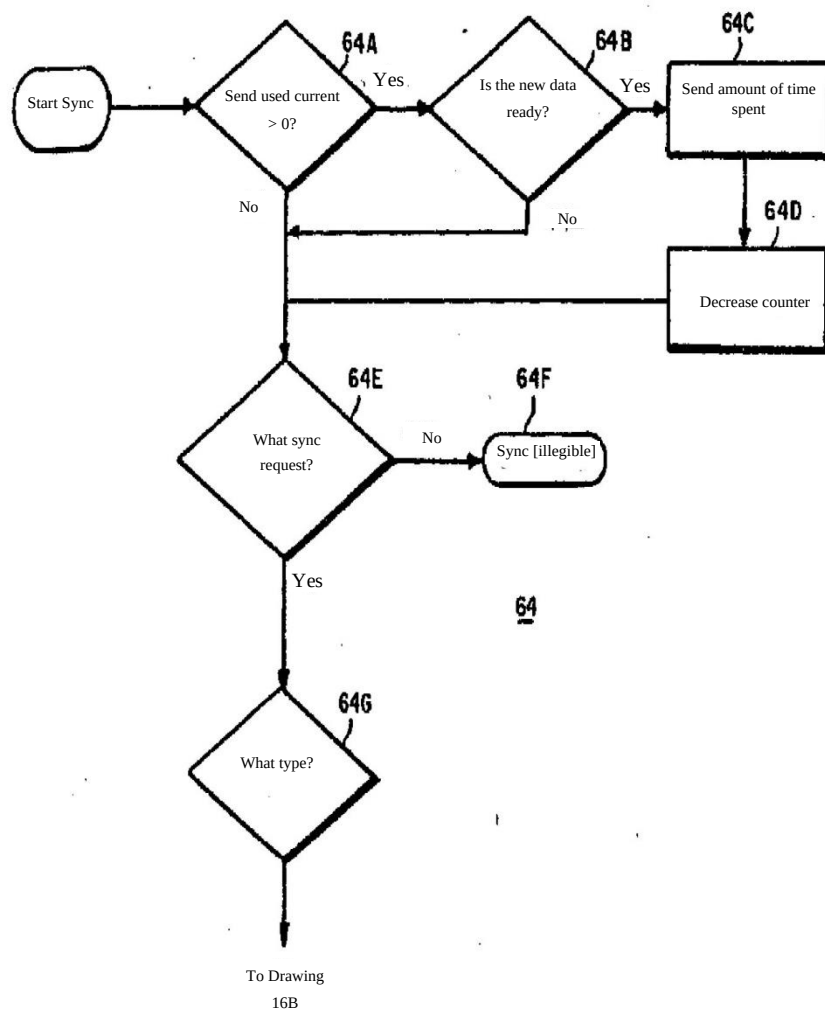
Date: WED, 12/14/94	Time: 02:14:20 PM	Total energy used today 8.0900 KWH \$0.49	Current Energy Load
------------------------	----------------------	--	------------------------

Current (illegible) (0.0800)

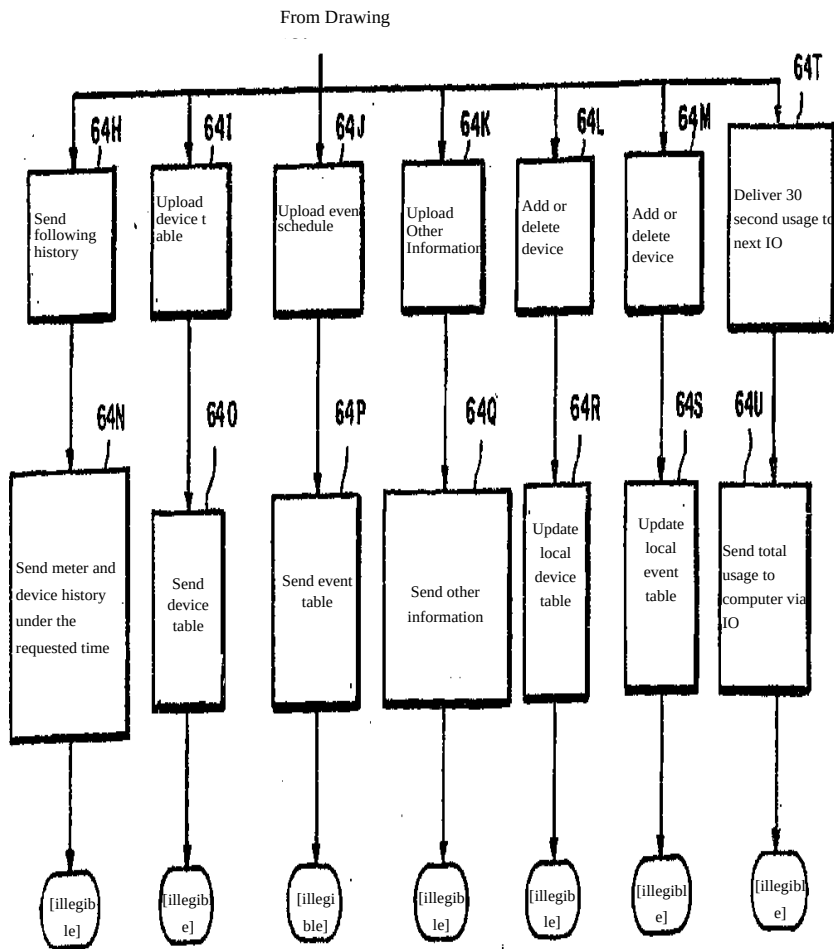
OK

Delete

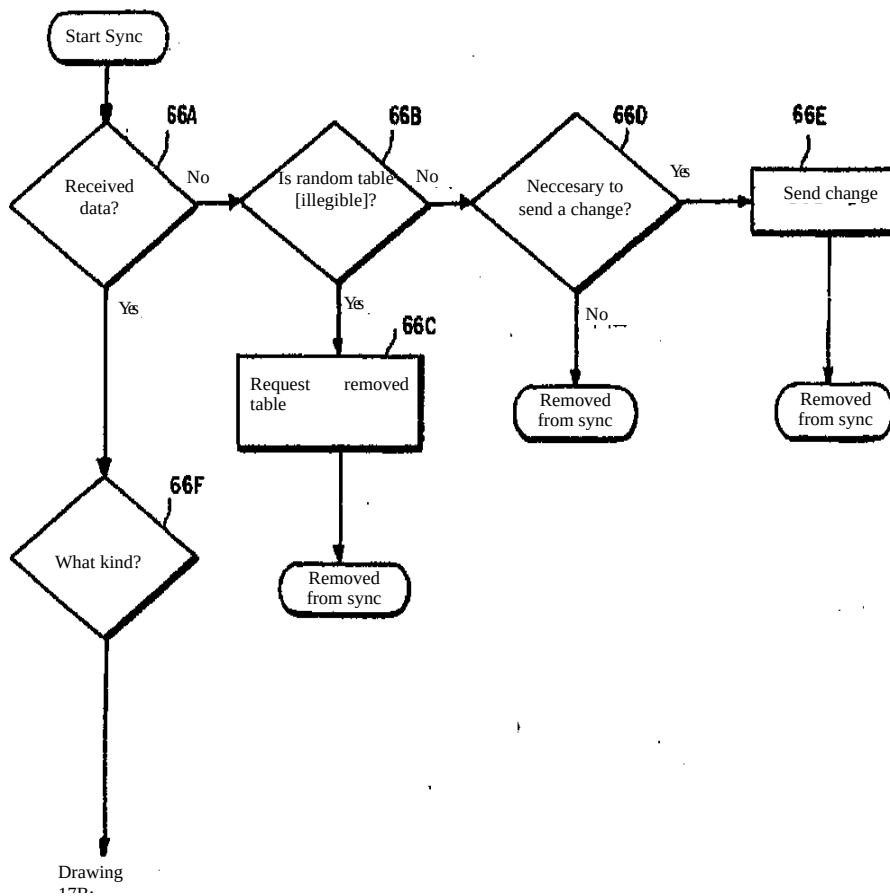
Drawing 16a



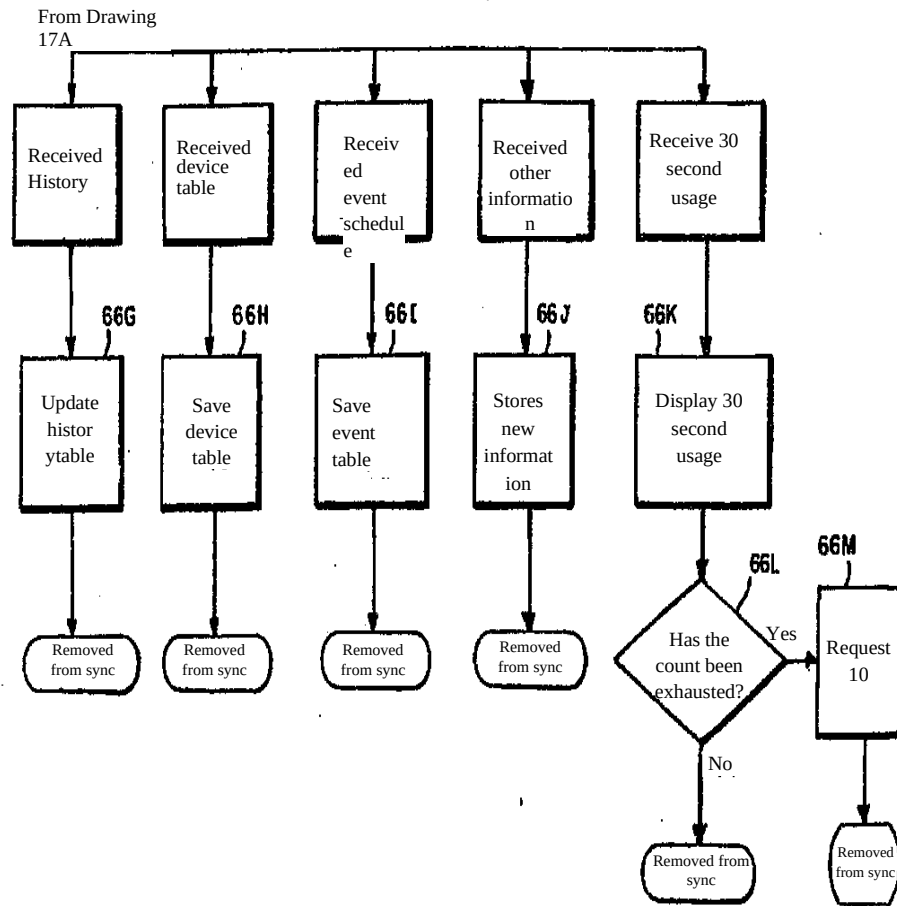
Drawing 16b



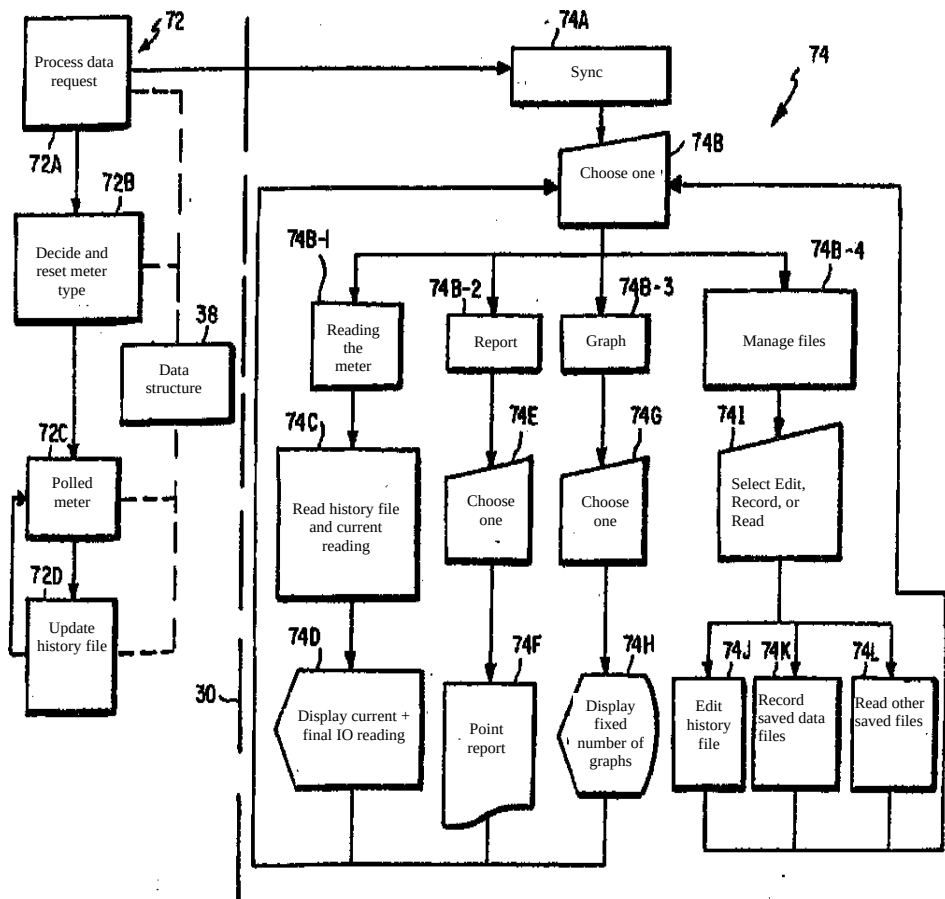
Drawing 17a

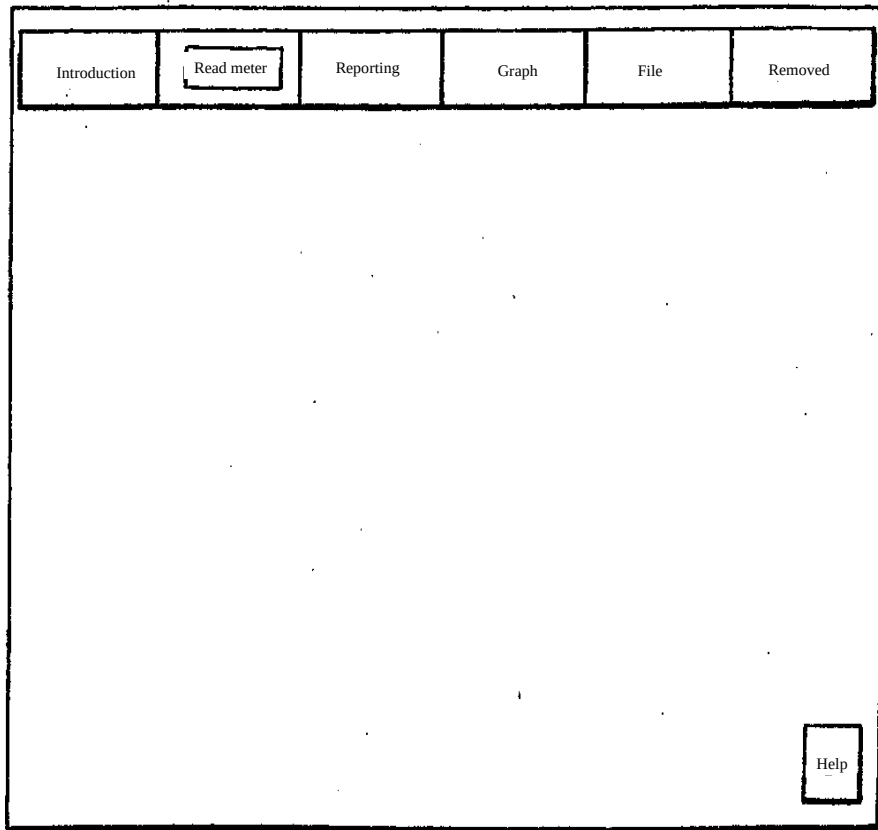


Drawing 17b



Drawing 18



Drawing 19

Drawing 20

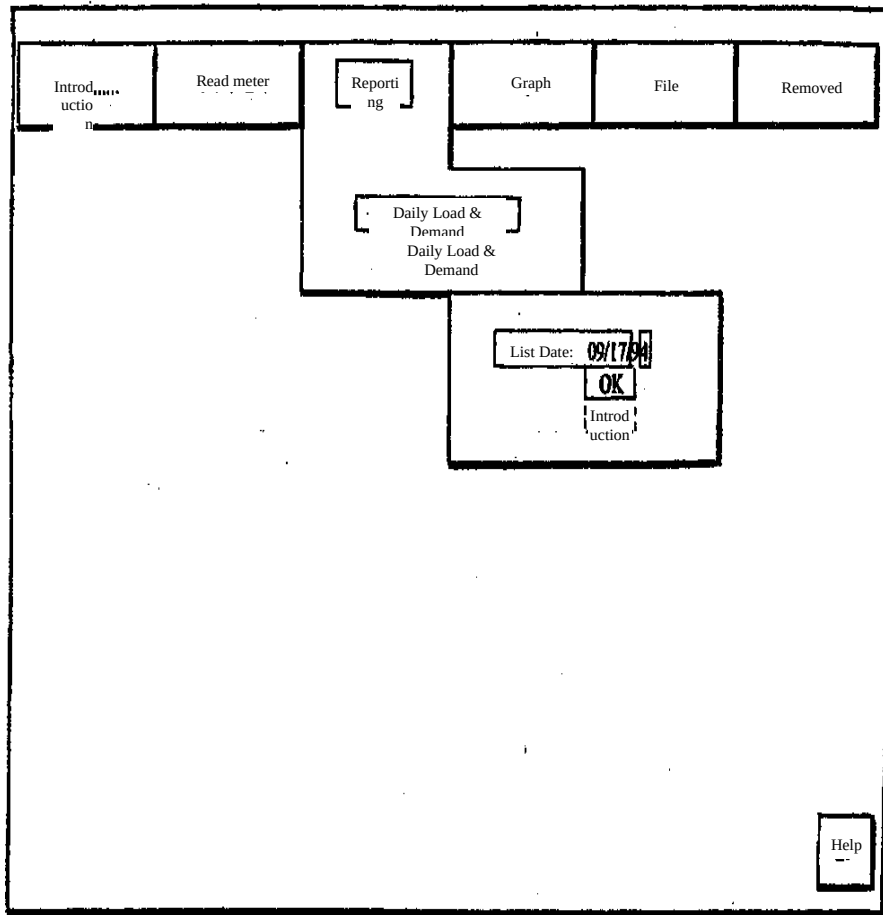
Introduction	Read meter	Reporting	Graph	File	Removed
--------------	------------	-----------	-------	------	---------

Current gradation: 0.0000

Date	Time	KWH	KVAH	KVARH
11/22/94	16:00-16:14	0.1388	0.1682	0.0978
11/22/94	15:45-15:59	0.1146	0.1373	0.0756
11/22/94	15:30-15:44	0.0624	0.0624	0.0000
11/22/94	15:15-15:29	0.0984	0.1044	0.0438
11/22/94	15:00-15:14	0.1410	0.1791	0.1104
11/22/94	14:45-14:59	0.0792	0.0823	0.0222
11/22/94	14:30-14:44	0.0624	0.0624	0.0000
11/22/94	14:15-14:29	0.1366	0.1714	0.1008
11/22/94	14:00-14:14	0.1092	0.1276	0.0660
11/22/94	13:45-13:59	0.0624	0.0624	0.0000

Help

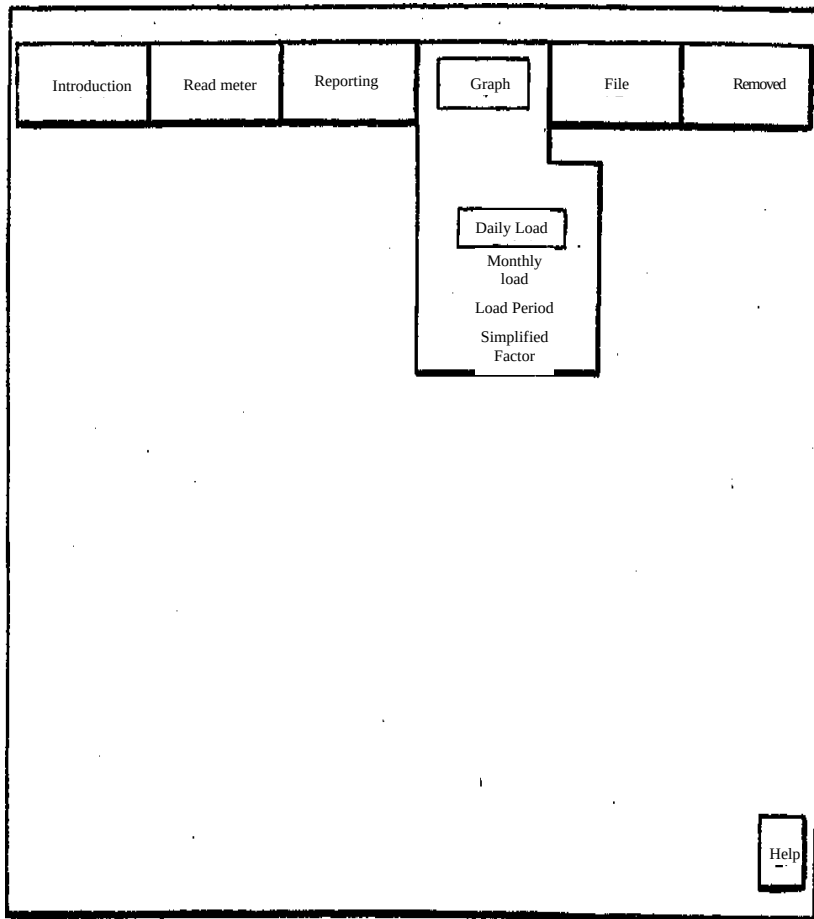
Drawing 21



Drawing 22

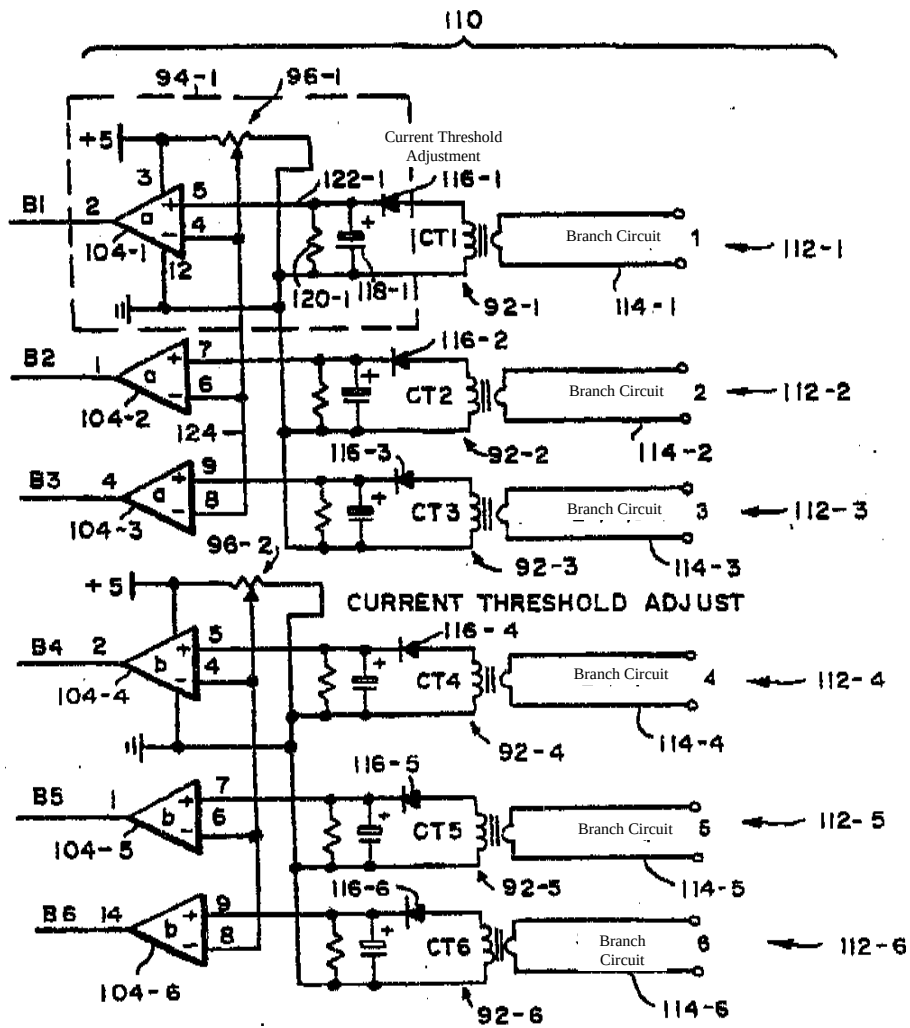
Daily Load & Saturday Demand 9/17/94					
Hour	KWH	KVAH	Hour	KWH	KVAH
0:	0.6582	0.7858	12:	2.0858	2.5157
1:	1.1784	1.2544	13:	1.9824	2.3850
2:	3.3060	3.8929	14:	2.0088	2.4698
3:	1.8120	1.9883	15:	0.5834	0.6814
4:	1.5008	1.5898	16:	0.5875	0.6832
5:	2.1444	2.3898	17:	0.5148	0.5838
6:	1.7826	1.8870	18:	1.1142	1.3463
7:	1.6188	1.7550	19:	3.1008	3.8782
8:	1.3158	1.3878	20:	2.1024	2.5746
9:	0.9808	1.0197	21:	1.6628	1.9898
10:	2.1402	2.3821	22:	1.2474	1.5355
11:	1.7888	1.8829	23:	2.5554	3.2072
Total:				39.7096	48.1856
Peak Time	KW	KVA	KVAR	Transfer Load	
2:30-2:44	3.8568	4.6765	2.8448	Acquisition	Acquisition
				0.04	0.43
Print + days - days End					

Drawing 23

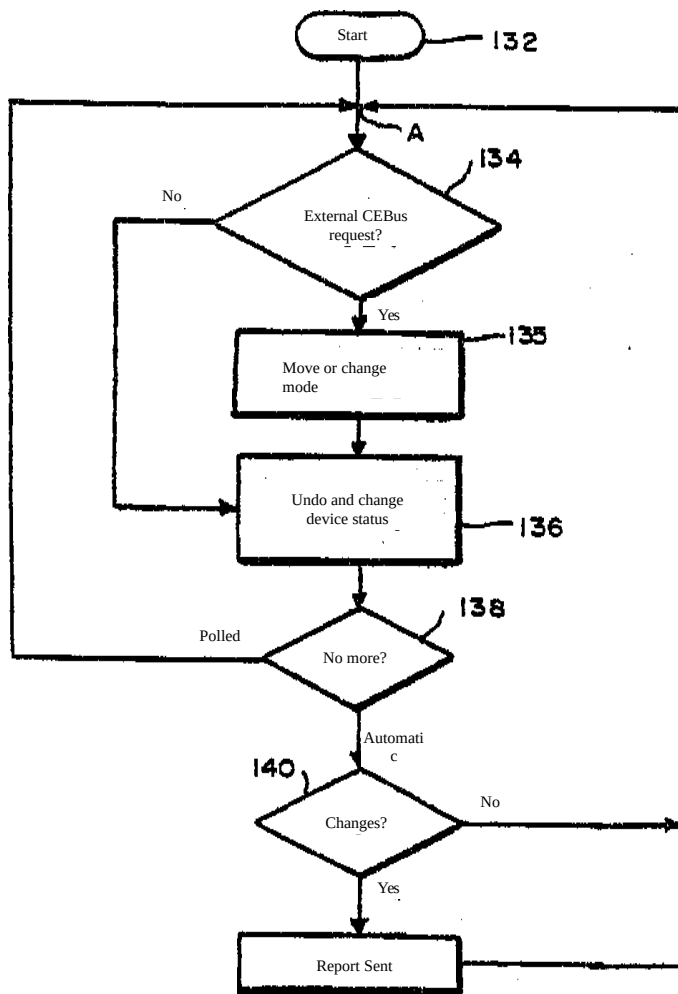




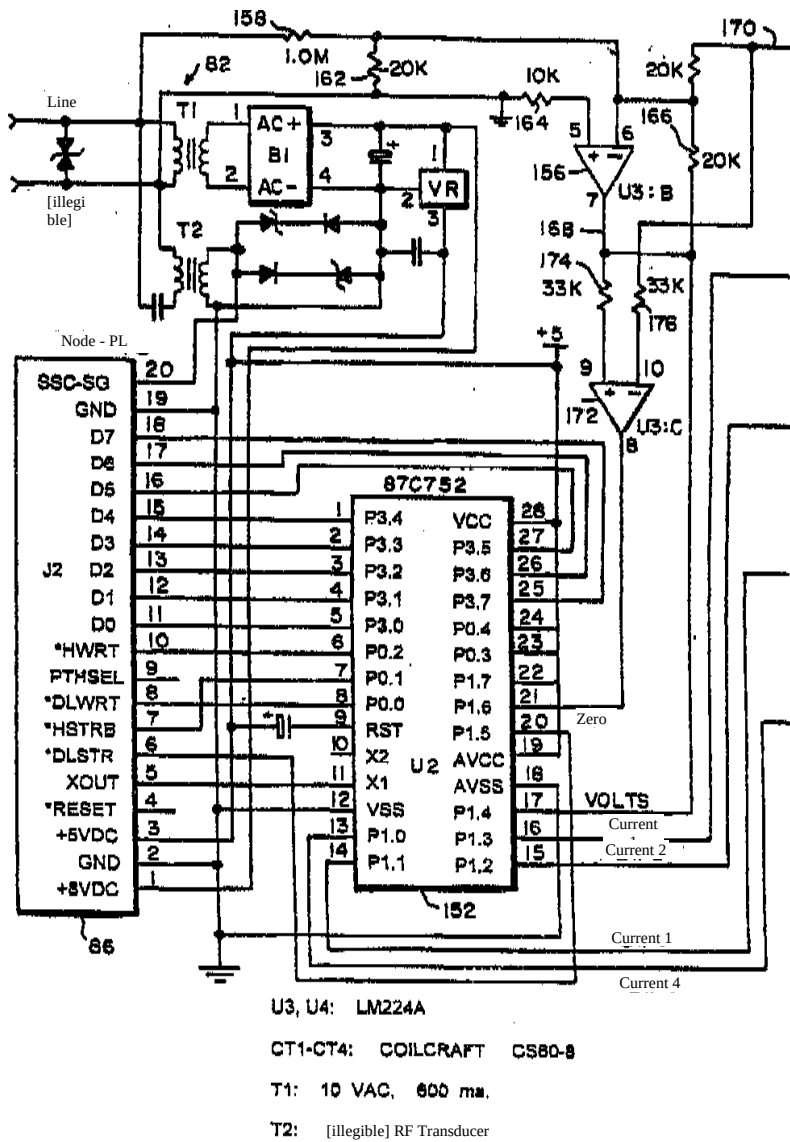
Drawing 24b



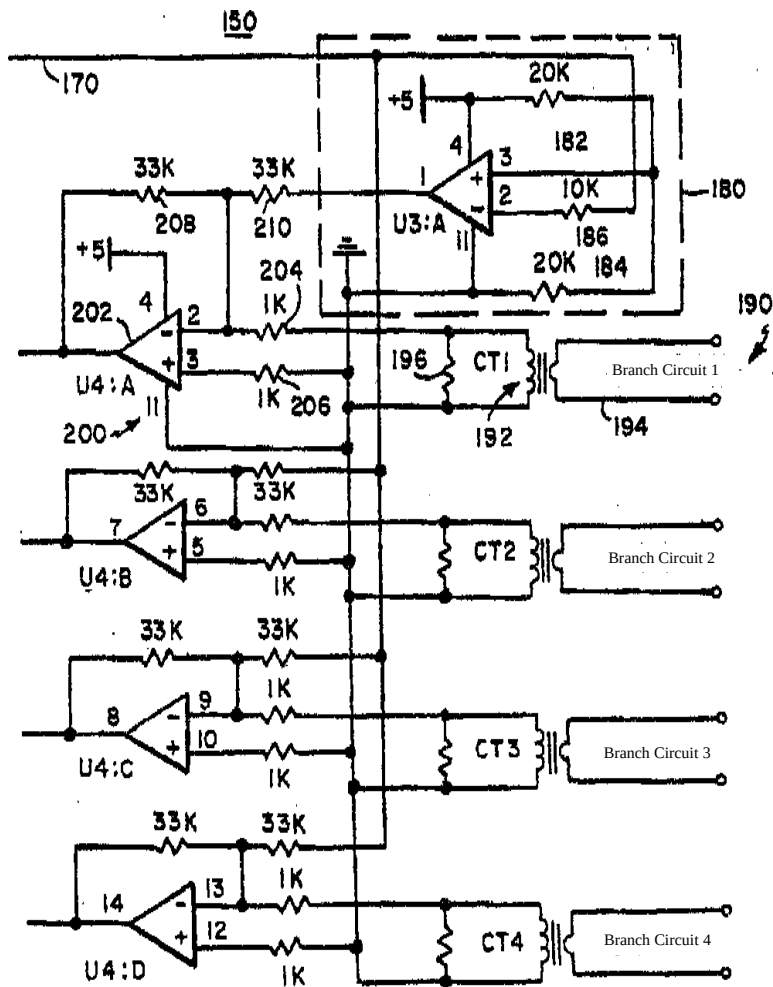
Drawing 25



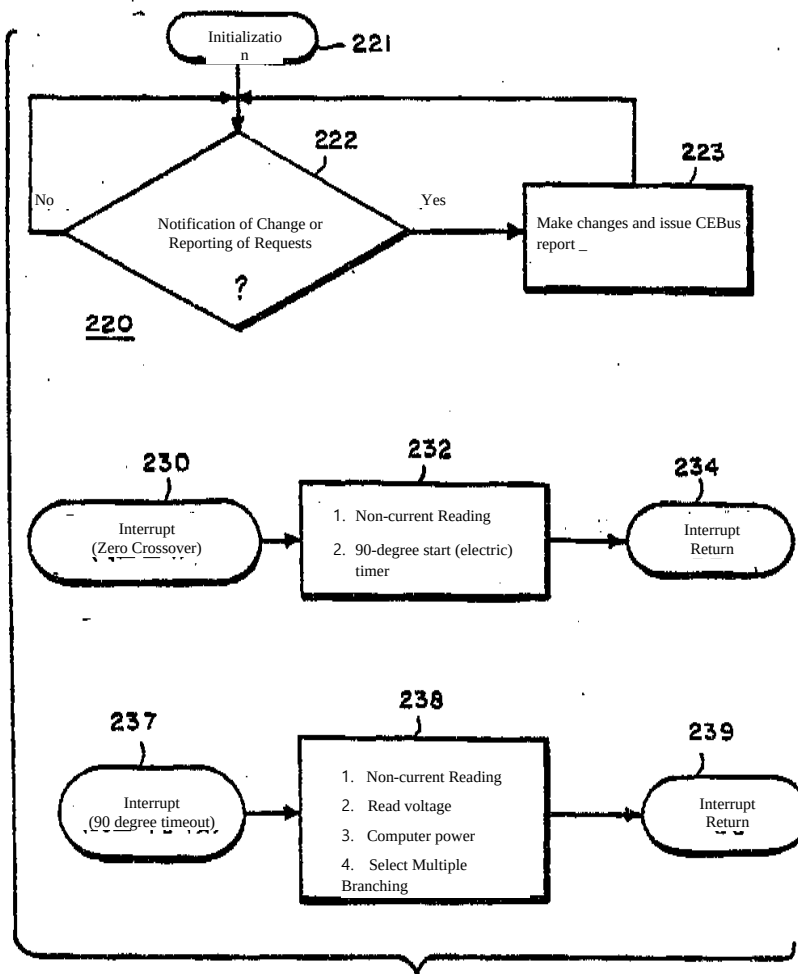
Drawing 26a



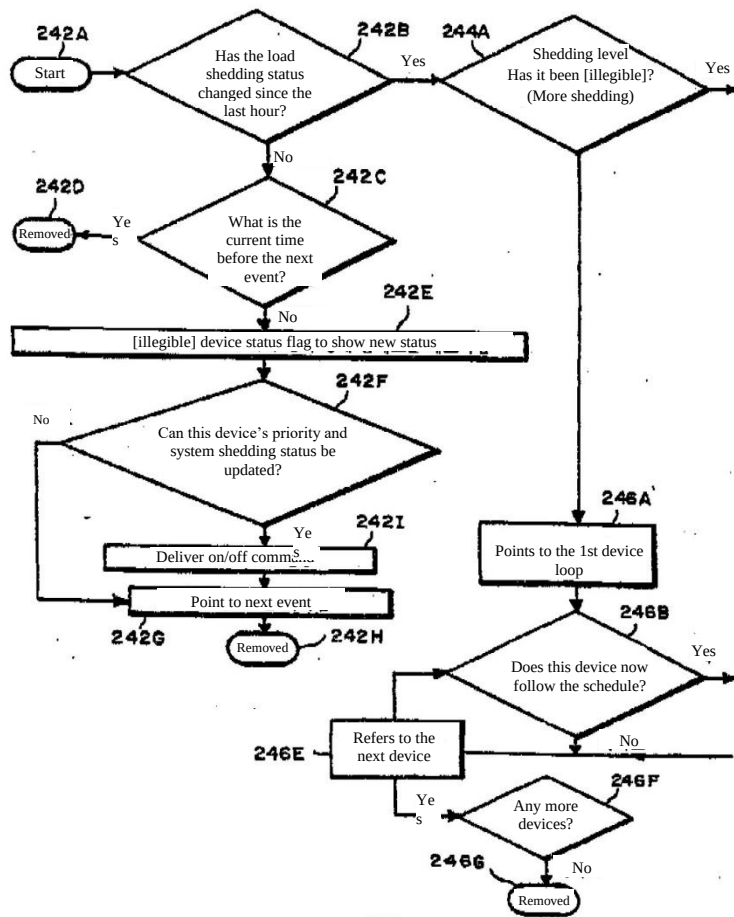
Drawing 26b



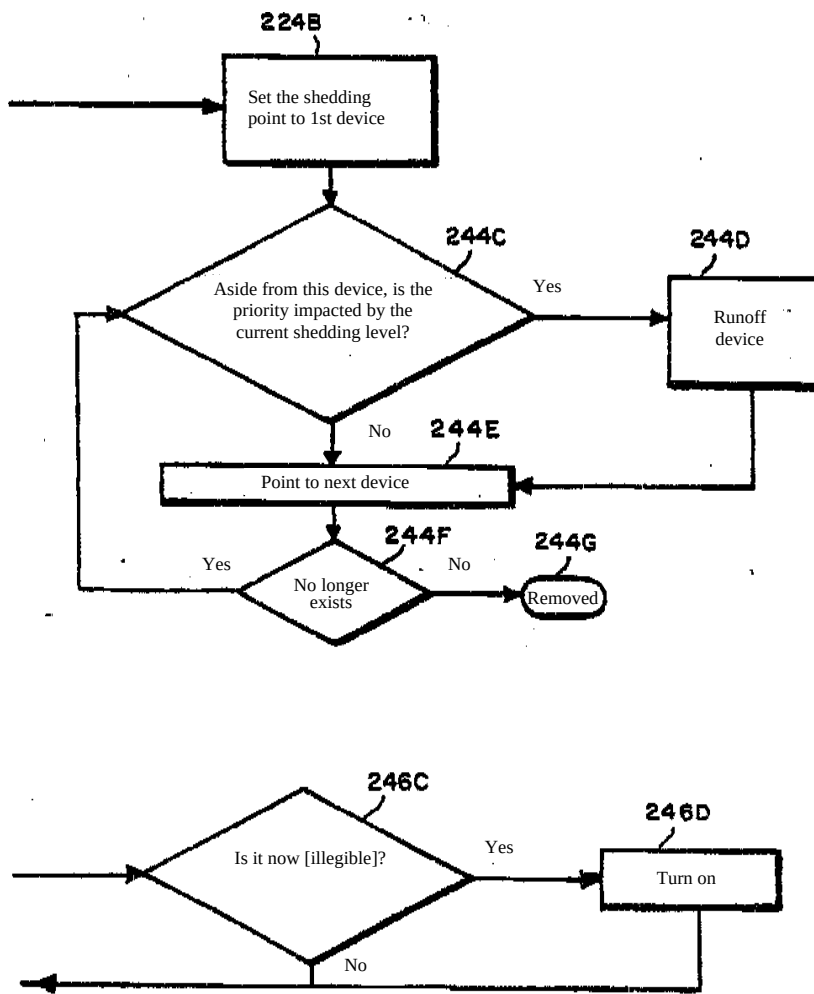
Drawing 27



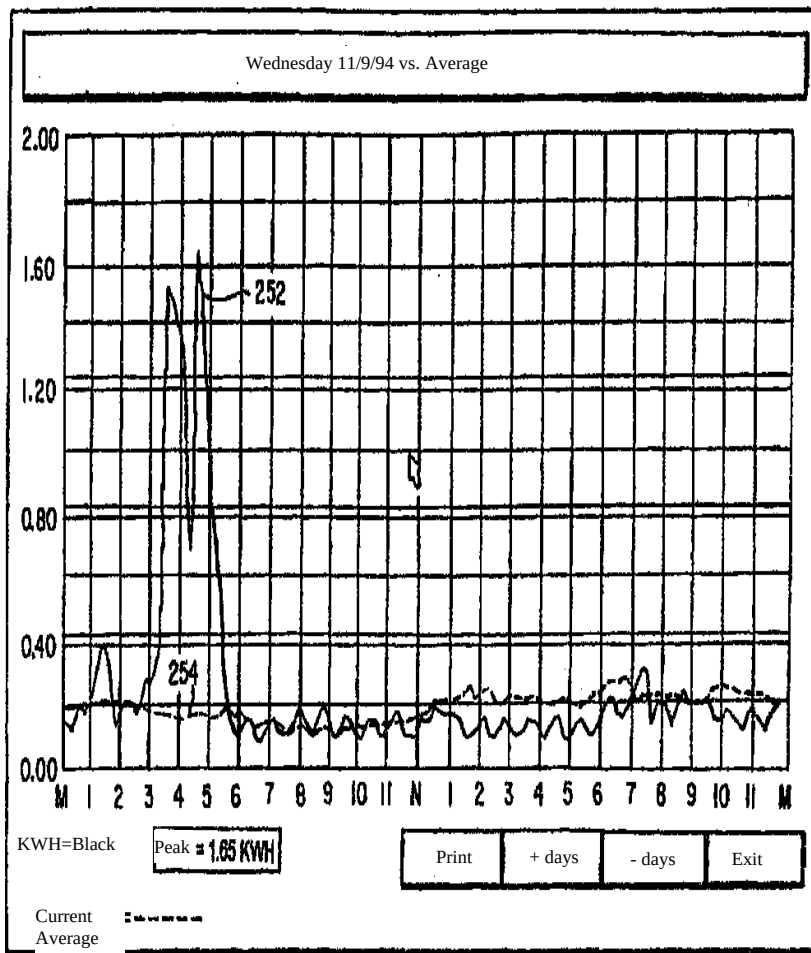
Drawing 28a



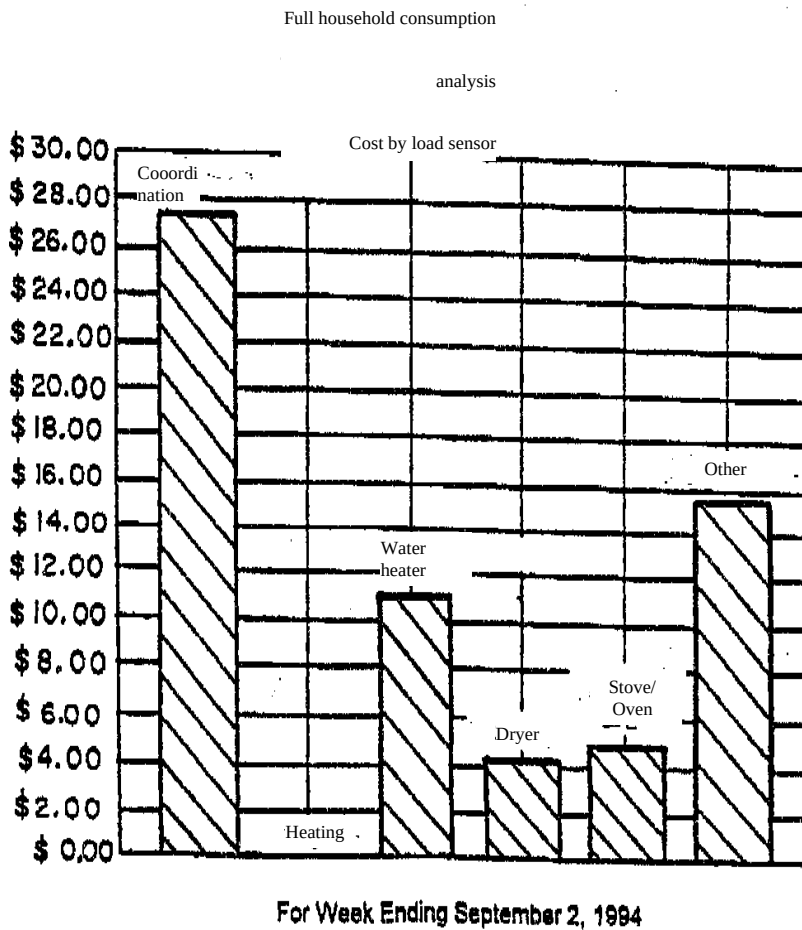
Drawing 28b



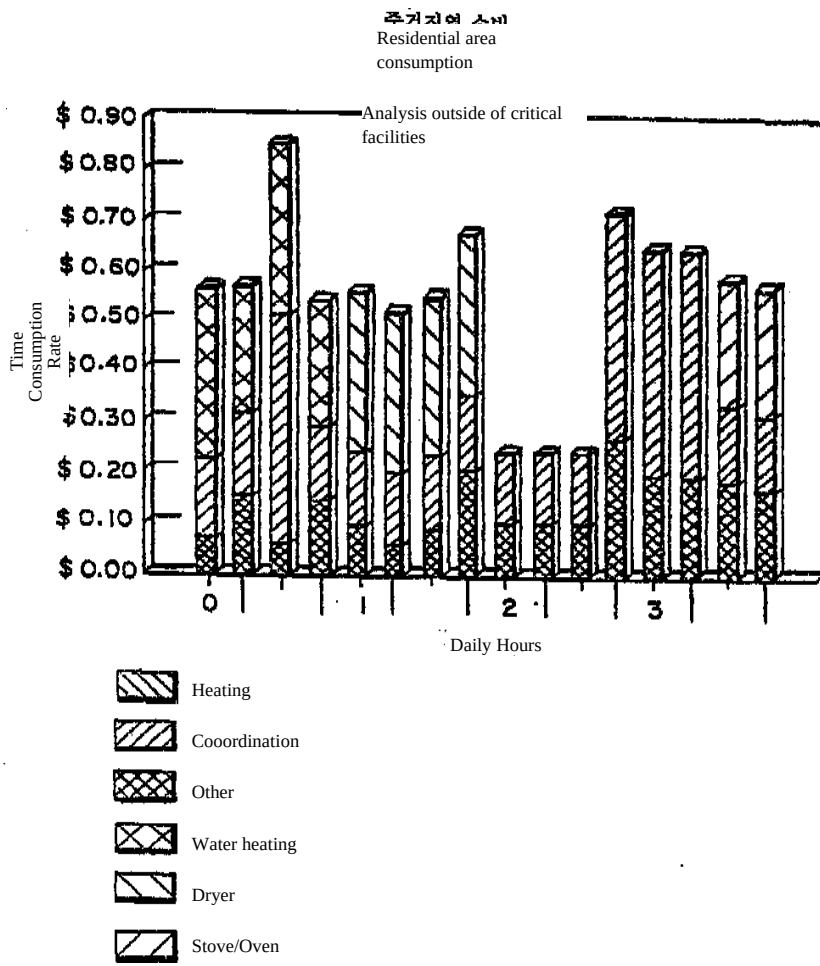
Drawing 29



Drawing 30



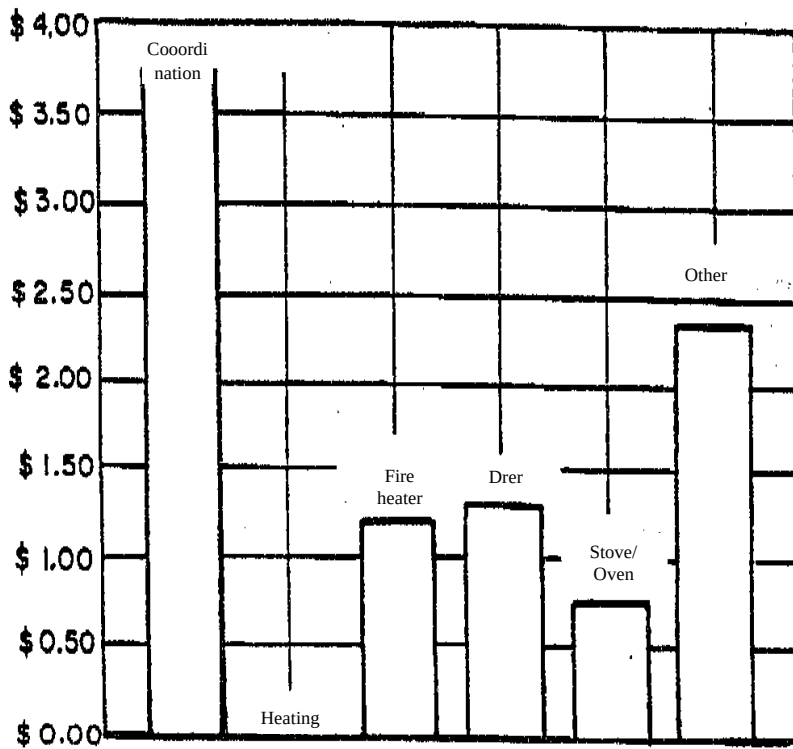
Drawing 31



Drawing 32

Full household consumption analysis

Daily Average Cost by Load Center



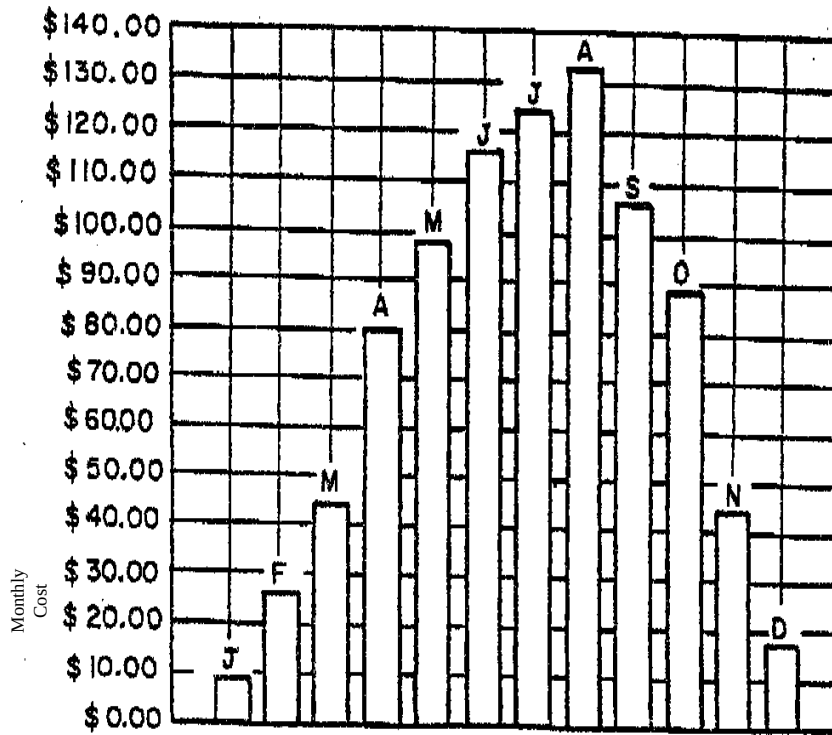
1994. 9. 1

Drawing 33

Full household

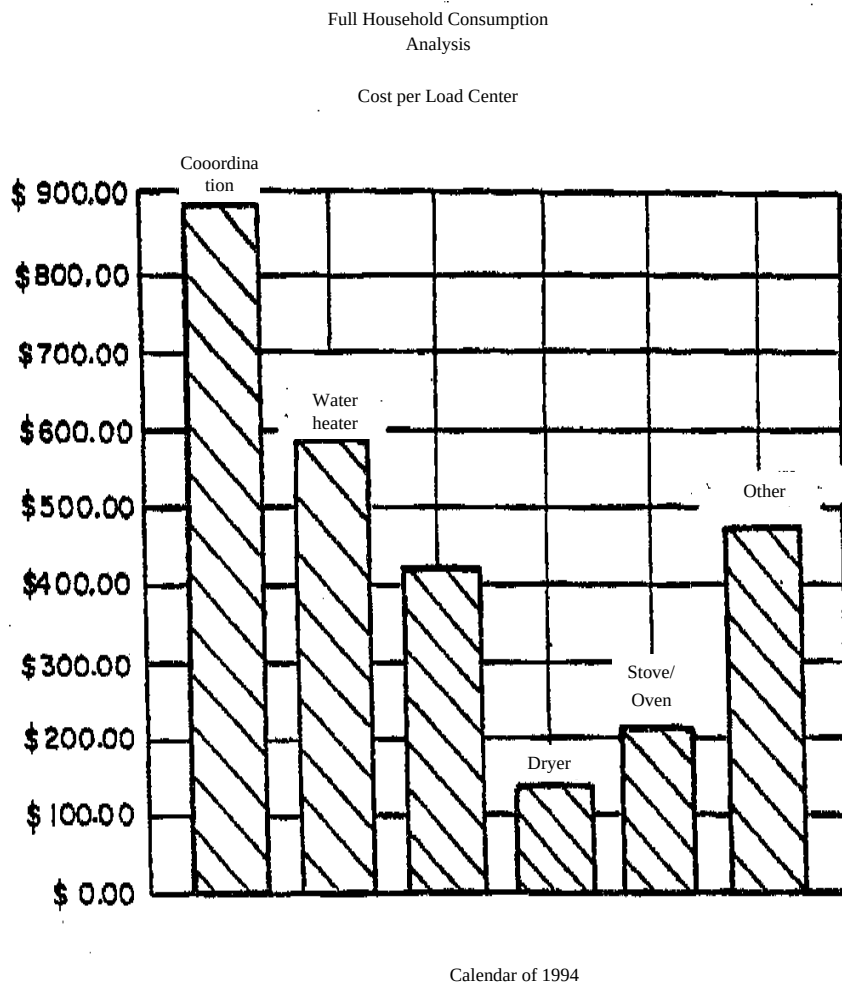
consumption analysis

Air conditioning costs

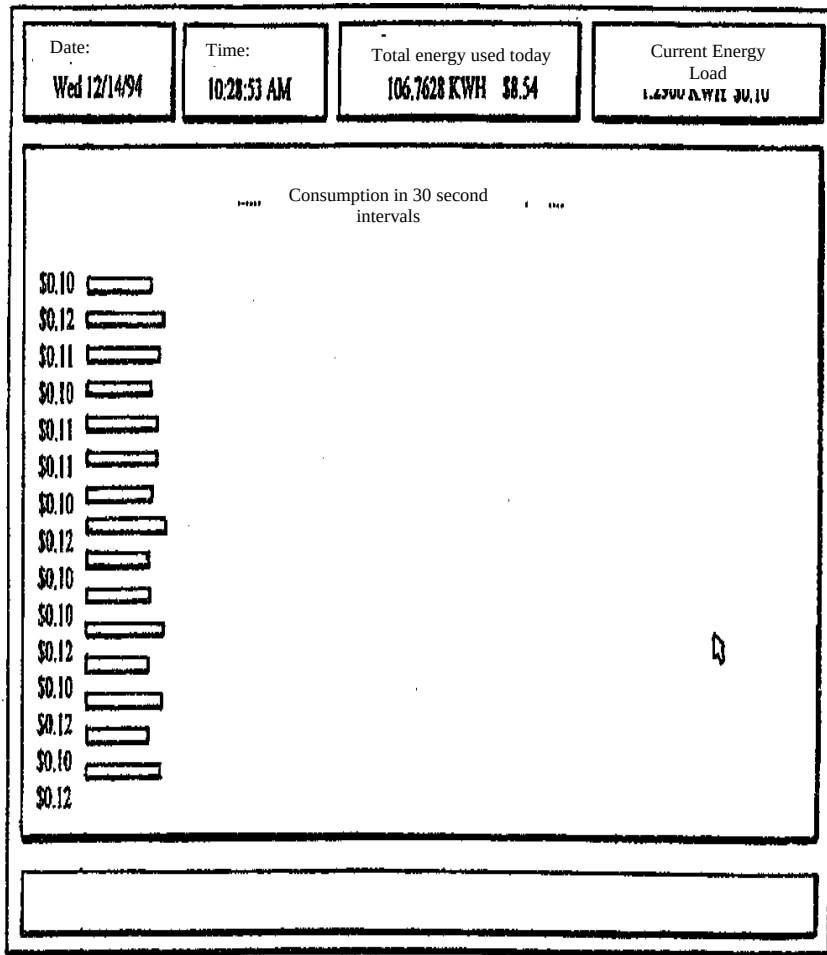


Calendar of 1994

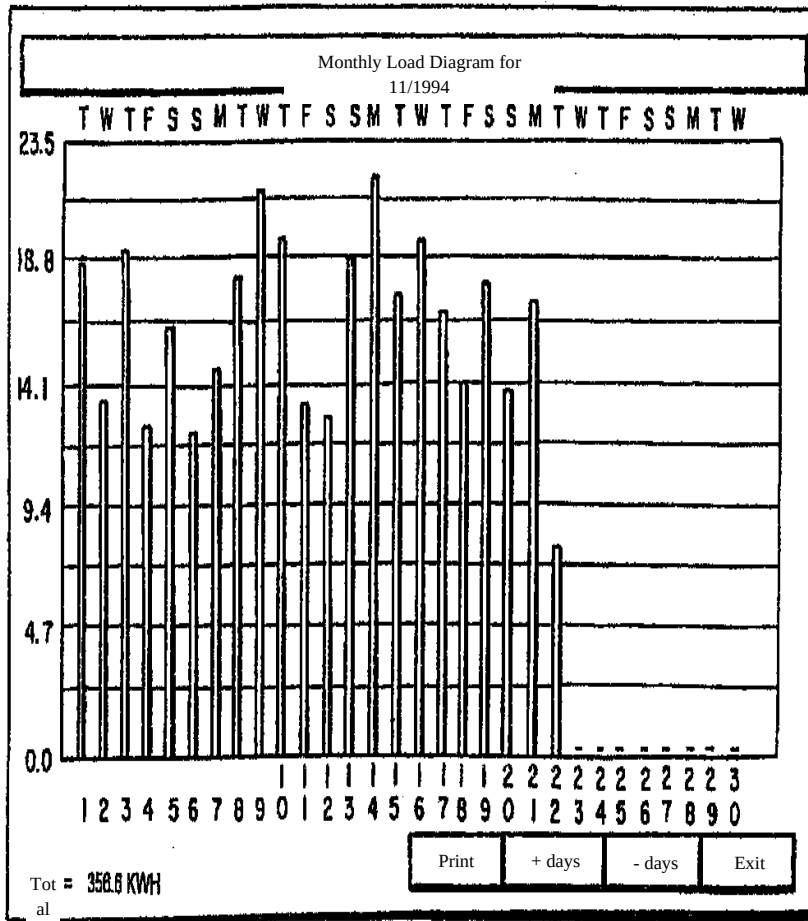
Drawing 34



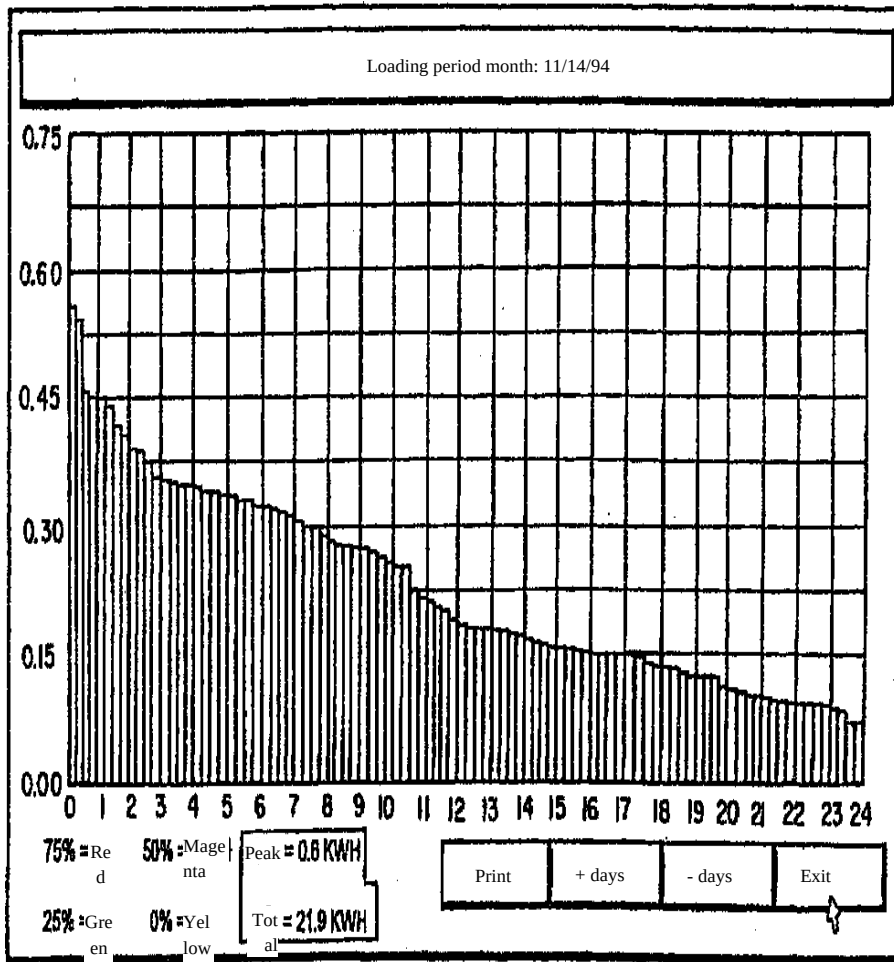
Drawing 35



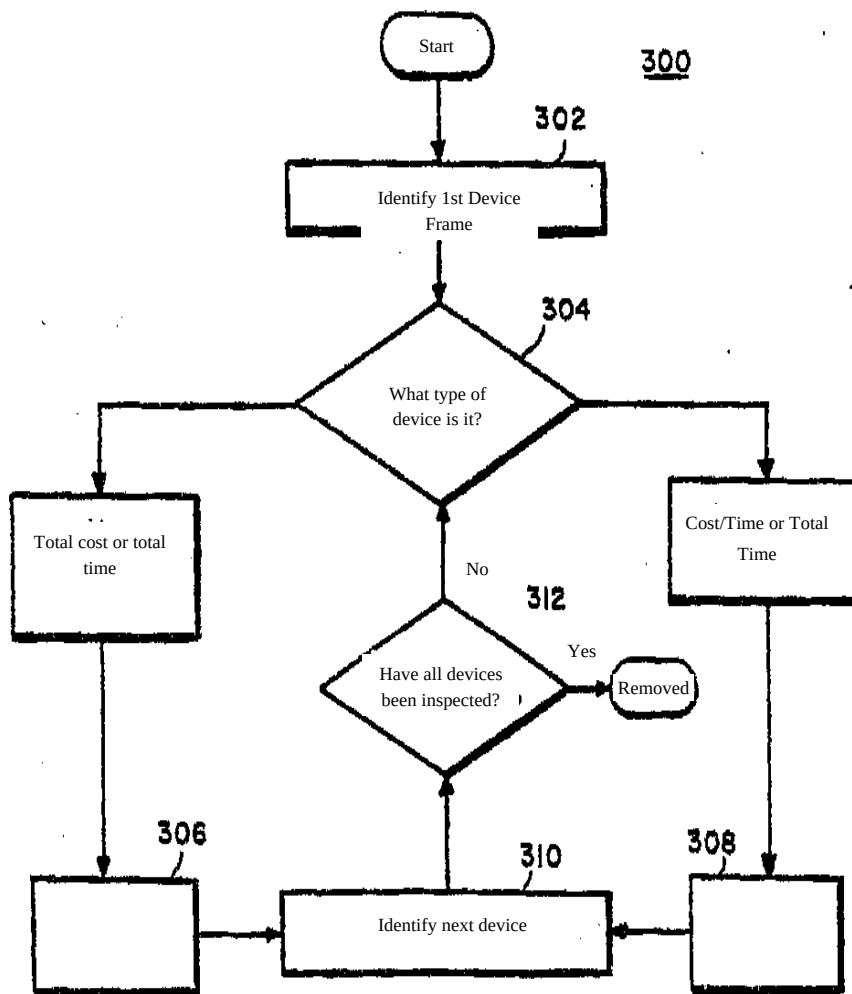
Drawing 36



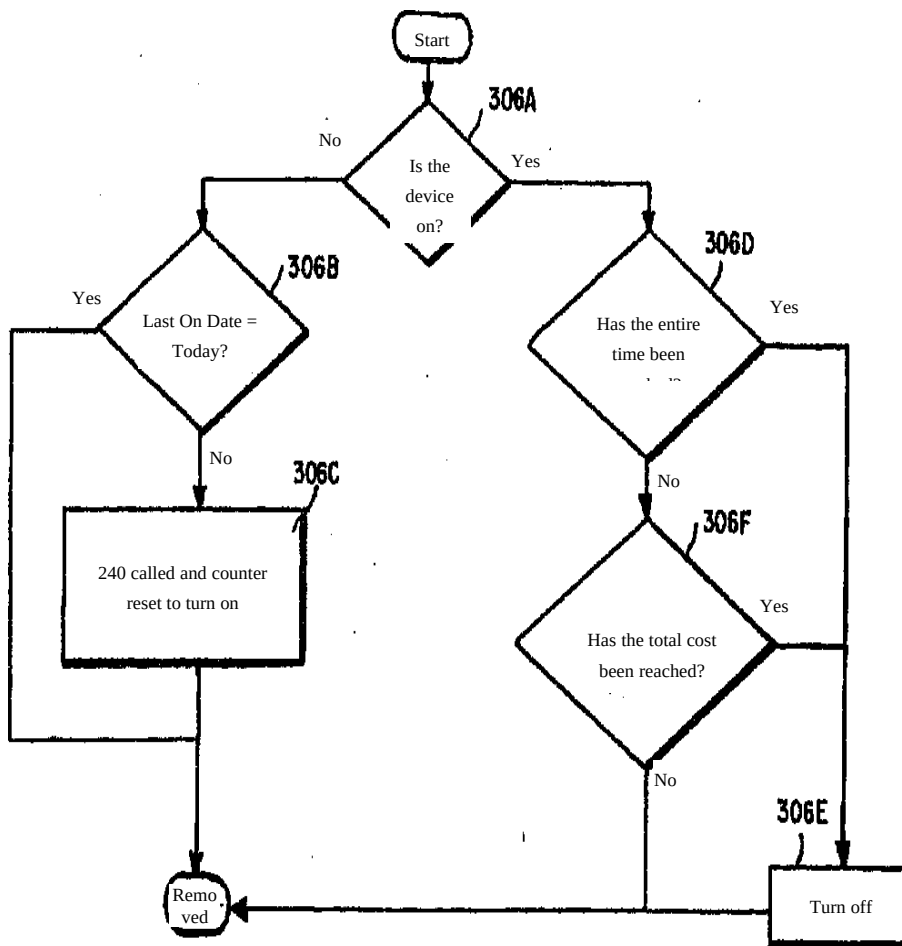
Drawing 37



Drawing 38



Drawing 39



Drawing 40

