Apparatus are described for monitoring the consumption of electricity supplied on a cable (20). The sensor includes an electricity sensor unit having at least one current transformer (21) housed in an electrically-insulative housing clamped over the cable to form an inductive, non-conductive coupling between the current transformer and the cable. The sensor unit includes an energy storage circuit (23) coupled to the current transformer and configured to generate power for the sensor unit, and a current measurement circuit (22) powered from the energy storage circuit and responsive to current induced in the current transformers to provide an output signal representative of the current that has flowed on the cable over a period of time. A switching circuit isolates and connects a burden resistor from and to the current transformer.
ENERGY METER WITH POWER SOURCE

FIELD OF THE INVENTION

This invention relates to apparatus for monitoring the consumption of a resource such as electricity, gas and water. Preferred embodiments of the invention relate more specifically to monitoring the consumption of electricity supplied on a cable, and more particularly to clamp-on energy-meters with power supplies for such monitoring.

BACKGROUND

Climate change is one of the greatest challenges facing humanity and energy use in buildings accounts for around 47% of carbon emissions from the UK at present. Efforts to reduce these emissions include technical efficiency improvements through more energy-efficient products, the use of renewable energy, and other large infrastructure and technology products such as micro-generation stations. Efforts are also required to change the patterns of energy use by consumers and it is the interaction between people and technology that makes energy usage a socio-technical issue. Demand can vary by a factor of two or more between identical buildings with the same number of occupants, and this suggests that reducing waste through behavioural efficiency is essential.

The UK government has recently announced the intention to require electricity suppliers upon request to provide home energy monitors to their customers: -This would represent significant capital costs to the utility suppliers, whose objectives are to acquire and retain customers and to increase the average revenue from customers by using existing and new products and services.

The utility suppliers, and in particular the electricity suppliers, recognise three major obstacles to progress in these strategic objectives: a shortage of sources of competitive advantage, a lack of detailed understanding of their customers, and a lack of "touch points", i.e. ways of interacting with the customers. Opportunities for differentiation revolve mainly around price and, to a much smaller extent, green issues i.e. issues that apparently reduce environmental impact. The utilities have very little information about their customers since the electricity and gas and water meters collect whole house data continuously and are read infrequently. The utilities do not have the opportunity to deliver their brand, i.e. to market
their services, in a positive way into the lives of their customers. Their current "touch points":
billing and customer services, have negative connotations.

Clamp-on energy meters can be particularly useful where the device is installed by a member
of the general public. These devices do not require interference with main electricity
connections. Traditionally clamp-on energy meters have been battery powered devices and
so require regular maintenance in changing the batteries. In some overhead power line
monitoring applications energy is harvested from the current flowing in the power line for
powering the monitoring devices circuitry. It is also known that some surge protection
devices use a current transformer both for temporarily powering the device and monitoring
for a surge condition.

SUMMARY

Accordingly, the purpose of the present invention is to provide technical means for improving
the acquisition of information on resource consumption by customers, and in the provision of
the energy usage information that is likely to be required in order to comply with government
regulations; all this in a way in which minimizes costs and environmental impact.

The present invention provides apparatus for monitoring the consumption of electricity
supplied on a cable, comprising: an electricity sensor unit having at least one current
transformer housed in an electrically-insulative housing clampable over the cable to form an
inductive, non-conductive coupling between the or each current transformer and the cable;
the sensor unit comprising: a power supply circuit coupled to the current transformer or to
one of the current transformers to generate power for the sensor unit; a current measurement
circuit powered from the power supply circuit and responsive to current induced in the, or in
one of the, current transformer(s) to provide an output signal representative of the current that
has flowed on the cable over a period of time; and a data communication circuit powered
from the power supply circuit and responsive to the output signal to transmit data
representative of the output signal to an external receiver.

From another aspect, the invention also provides apparatus for monitoring the consumption
of electricity supplied on a cable, comprising: an electricity sensor unit having at least one
current transformer housed in an electrically-insulative housing clampable over the cable to
form an inductive, non-conductive coupling between the or each current transformer and the
cable; the sensor unit comprising: a power supply circuit coupled to the current transformer
or to one of the current transformers to generate power for the sensor unit; a current
measurement circuit powered from the power supply circuit and responsive to current
induced in the, or in one of the, current transformers) to provide an output signal
representative of the current that has flowed on the cable over a period of time; and a data
processor and memory circuit powered by the power supply circuit and configured to be
responsive to the output signal to process and store data representative of current
consumption on the cable over a period of time.

Another aspect of the present invention encompasses clamp-on energy meters. As was
described previously, with existing clamp-on meters the changing of the battery is not the
preferred option due to the inaccessibility of the device when installed in a meter cupboard.
Further, the use is exposed to more interaction with mains wiring, in order to avoid changing
the battery and its perceived difficulties, embodiments of the present invention include
clamp-on energy meters that obtain, using a current transformer, the energy for related
circuitry from the supply that is monitored. To enable such devices to be handheld and low
cost, the invention uses the same current transformer for both metering and energy harvesting
applications.

Whilst the inventions described above are limited to electricity supply, another aspect of the
invention provides apparatus for monitoring the consumption of a resource supplied on a
conduit, comprising a resource consumption sensor unit connected to the conduit to allow it
to measure consumption of the resource; and a data communication circuit arranged to
transmit data representative of the resource consumption sensed by the sensor unit.

Preferred embodiments of these inventions are capable of providing the resource supplier,
such as the electricity utility company, with a platform of customer knowledge on which it
can build customer offerings. It also allows the supplier to comply with likely future
requirements for home energy monitors.

Preferred embodiments of the invention are capable of supply in a modular fashion as a
family of products rather than a single device, allowing the system to be expanded further and
for it to be tailored to particular needs.

Further preferred embodiments of the electricity monitoring apparatus may be fitted by clamping in a single process without the need for maintenance there are no batteries to be
changed, and data on consumption can be stored for example for up to five years in a secure fashion.

By integrating the computer memory with the sell powered electricity sensor or other resource sensor, the sensor unit may be placed adjacent an existing electricity meter in a safe part of the customer's house, for example, minimizing risk to the computer memory from impact or other influence. There is no need for any cabling between the memory and the transformer, in the preferred embodiment, which would introduce risks of damage.

The clamp for the current transformer or transformers in the preferred embodiment can be made to fit universally, so that a single configuration of clamp should be sufficient to meet all needs, reducing manufacturing costs substantially.

The provision of detailed consumption information including energy savings related to cost means that the customer is more likely to be informed, educated and even entertained. The provision of a public display of energy savings achieved by a particular customer is likely to incentivise that customer to make the savings by changing his consumption habits. For example, the effect of changing electricity consumption in just one appliance can be demonstrated. Further, the displays offer the supplier the opportunity of displaying its brand and the ways it can differentiate its services from its competitors.

The customer relationship management application in the computer network of the preferred embodiment allows the utilities to build customer offerings, for example by providing high value activities that will address their strategic and tactical challenges: strategic customer targeting, tariff design, tactical customer targeting, bill estimation and identifying new sources of revenue.

In preferred embodiments, the data processing within the network is arranged to allow the customer to tailor an energy saving programme to himself, and to set his own targets for energy savings. This further incentivises the customer to improve energy efficiency for the sake of reducing costs and reducing environmental impact.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be better understood, preferred embodiments will now be described, by way of example only, with reference to the accompanying diagrammatic
drawings in which:

Figure 1 is a schematic diagram of the overall system embodying the invention for monitoring resource consumption of one location such as a house;

Figure 2 is a schematic diagram of an electricity sensor unit embodying the invention;

Figure 3 is a schematic diagram of a user display unit for use in the system of Figure 1;

Figure 4 is a schematic diagram of the data return path shown in Figure 1;

Figure 5 is a schematic diagram of an electricity appliance sensor unit for use with the system shown in Figure 1;

Figure 6 is a schematic diagram of a public window display unit for use with the system shown in Figure 1;

Figure 7 is a schematic circuit diagram of one example of the sensor unit of Figure 2;

Figures 8, 9 and 10 show alternative examples to that shown in Figure 7, using a single current transformer instead of two current transformers; and

Figure 11 is a schematic circuit diagram of a further alternative example which includes a metered battery charger.

Figure 12 depicts a diagrammatic perspective view of an embodiment a clamp-on energy meter coupled to a power line, in accordance with the present invention.

Figure 13 is a diagrammatic side view with circuit diagram of an embodiment similar to that shown in Figure 12.

Figure 14 is a schematic block diagram of an embodiment of a clamp-on energy meter similar to those shown in Figures 12 and 13.

While certain embodiments are depicted in the drawings, the embodiments depicted are illustrative, and one skilled in the art will appreciate that variations of those shown, as well as other embodiments described herein, may be envisioned and practiced within the scope of the present disclosure.
DETAILED DESCRIPTION

Apparatus for monitoring the consumption of a resource, and embodying the present invention, is shown in Figure 1. The resource may be electricity, gas or water, supplied to a domestic consumer or to a business consumer through a conventional meter for recording consumption. It may be micro-generated electricity or fuel. Each resource is supplied through a conduit such as a cable or pipe with the meter in series. In some cases, however, the resource may be supplied directly to an appliance. In the preferred embodiment of the invention, and as described further with reference to Figures 2 to 13, the resource is electricity supplied on a cable.

The resource sensor 1 responds to the flow of the resource along the conduit, such as the electrical current along the cable, to provide outputs indicative of the resource consumption to a universal sensor reader 3, a display unit 4, a data return path 5 connected to a computer network 7 to 13, and a public display or public window display 6. The resource sensor 1 communicates interactively with a smart meter 2 which is in series with the conduit and which has a communications facility.

The universal sensor reader 3 is a wireless, portable, rugged, hand-held device as used by energy supplier businesses to read sensors periodically. As shown in Figure 1, the universal sensor reader 3 receives a radio output from the resource sensor 1, indicative of the resource consumption over a period of time; it then communicates this data, either immediately or at a convenient time in the future, to a resource and cost management application 12 on the computer network.

The computer network includes a user PC (Personal Computer) or router 7 (which may be wireless) which comprises a client application program 8 and a daemon program 8 running in the background, together with a web browser 9, connected by way of a TCP/IP connection to the Internet. This enables communication over the Internet to the remainder of the computer network, which comprises a services API 10 intercommunicating with a diet application 11 and with the resource and cost management application 12. Both the diet application and the resource and cost management application 12 provide outputs to a customer relationship management application 13 intended for third parties such as the energy supplier businesses.

The diet application 11 controls the way in which the resource consumption is monitored and controlled in accordance with customer requirements. It interfaces with the user PC or router
7 through the services API 10 which is the Application Programming Interface. By way of example, the customer enters data interactively on his user PC 7 to indicate the nature of the energy savings he wishes to make, and to enter a schedule or program of ways of achieving this, by changing the pattern of energy consumption in each major appliance in his house. This is recorded in the diet application 111 which interacts with the customer relationship management application 13. The resource and cost management application receives data relating to the tariff from the customer relationship management application 13, and receives resource consumption data from the user PC or router 7 through the network. It provides the supplier with data on the pattern of consumption over a period of time, and it is capable of transmitting data back to the domestic system 1, 5, 7 for controlling consumption. Using an individual appliance sensor 70 shown in Figure 5 and described in greater detail below, with a data link 75 to the data return path 5 of Figure 1, it is possible to issue commands to each appliance to control its program of consumption. For example, heaters could be controlled to switch off for a period during the night. In a regional blackout or brownout, where there is a general limitation on the electricity grid, inessential appliances can be temporarily switched off or their rate of consumption reduced, using this control system.

An example of the resource sensor in the form of an electricity sensor unit 1 is shown in Figure 2. The sensor unit 1 has an electrically-insulative housing containing preferably just one, but optionally two current transformers (CT) 21, examples of which will be described in more detail below with reference to Figures 7 to 11. Each CT 21 is permanently clamped around the live power cable 20 for mains electricity, normally in the vicinity of the electricity meter which is typically protected in a cupboard. Thus the sensor unit 1 is supported entirely by the cable. The sensor unit 1 has a wireless radio link 25 to other parts of the system which rely on the electricity sensor for data.

The housing of the sensor unit 1 further comprises current measurement circuitry 22 and power storage and management circuitry 23 both responsive to induced current in the CT 21. The power storage and management circuitry 23 obtains power from the live power cable 20 in a parasitic fashion through the inductive coupling. It includes electricity storage, typically a rechargeable battery, which would not normally require replacing for at least 5 years.

A microprocessor 27 at the heart of the sensor unit 1 has a memory unit 28 safely stored within the housing of the sensor unit 1, and it receives data from a real time clock 26 indicative of the current time. The microprocessor 27 has an expansion port 29 which
interfaces with an external sensor or smart meter or any other peripherals 30. However, in some embodiments the data links with the sensor, meter and any other peripherals could be wireless, so the expansion port may be different or may be unnecessary.

The current measurement circuitry 22 integrates the current from the current transformer 21 to provide an output signal indicative of current flowing in the live power cable 20, and this output signal is fed to the microprocessor 27 and stored in the memory 28. The memory 28 is arranged to store current consumption data for a large period of time, and is protected from interference or tampering so that it cannot be confused with data for other consumers. Typically, the memory 28 is arranged to provide high resolution data with samples at 5 second intervals over a period of 90 days; and low resolution data, with samples at 15 minute intervals, over a period of 5 years, as an archive. This dual formatting approach provides the consumer and the supplier with appropriate data whilst minimising requirements on storage and transmission bandwidth. The high resolution data is used for recent historical analysis of energy use for display on the display unit and/or on the PC. The low resolution data is used over a period typically longer than 3 months for historical analysis of resource use.

By locating the computer memory at the point at which current is sensed, this reduces the likelihood of failure through transmission over a cable or a wireless link.

The use of induction as a source of power for the sensor unit is reliable and provides a continuous power source. It is used together with a rechargeable battery which provides primary power.

The sensor unit 1, which is the primary point of storage of data, has the minimum possible risk of being lost or damaged, for example through impact, by being placed in the meter cupboard. This is achieved by separating the sensor unit 1 from the user display unit 4.

By providing continuous background logging, regardless of any input from the customer, the data are reliably recorded for reading periodically by the supplier, whether through the network or by means of the universal sensor reader 3.

Data may be stored in the memory 28 using two different strategies depending upon the mode of use: a record at regular intervals, and/or a record whenever there is a change.
To provide the highest security against tampering or data loss, encryption is used to protect the data when it is transmitted. Encryption programs are changeable over time with software updates.

The user display unit 4 is shown in greater detail in Figure 3. This is a separate unit from the sensor unit 1, and it is normally placed in a convenient location within the home so that it may be read easily by the customer and it may communicate easily with the customer's PC or router 7 through the data return path 5. A microprocessor 49 receives power from a power storage and management unit 45 connected to a rechargeable battery 42 and also to an external power source of alternating current (AC) 41, or alternatively a solar cell which may be external or else mounted on the housing of the display 4. A real time clock 43 provides information on the current time to the microprocessor 49, and is powered from the power storage and management circuit 45. The display 4 communicates wirelessly by radio through link 47 with the sensor unit 1; in alternative embodiments, the connection may be through a cable. A buffer unit 46 stores this data obtained by the RF link, indicative of the electricity consumption over a period of time. This information is provided to the microprocessor 49.

A temperature sensor 50 for sensing ambient temperature provides temperature data to the microprocessor 49, and this is used in connection with the requirements for heating and can affect energy consumption levels.

The display unit 4 contains two displays: a graphical screen 44 such as an LCD screen, for displaying text and/or graphical information; and an ambient array 51 controlled by a driver 48. The ambient array 51 is typically one LED (light emitting diode) which indicates the status of the monitoring apparatus, such as whether electricity consumption on the cable is above a predetermined threshold. The display 51 may alternatively be two or more LEDs, for example with different colours. A low power red and green and blue (RGB) light emitting diode is the preferred form of ambient display. The graphical screen display 44 includes areas for displaying information relating to electricity consumption, together with tariff information and energy savings and the like, and can include the logo of the electricity supplier company. The display on the graphical screen can rotate between several modes of operation, in response to user input to the microprocessor 49, for example through buttons or other controls such as a touch pad.
The display 4 preferably also includes a speaker 53 for providing an audio output to the user, indicative of power consumption or other information.

A USB controller 52 provides an interface for the user's PC or router 7 and for power input, if required, to the power storage and management unit 45.

Although not shown in Figure 3, the memory for the microprocessor 49 may include external memory such as portable, non-volatile memory including flash memory.

The entire system continuously tends towards a state of the lowest possible power consumption. This can be managed by the power storage and management circuit 45 in response to user input. User input into the system, for example through display unit interrogation, increases the system's state of readiness, making the sensor unit 1 more responsive. This is achieved by putting the sensor unit 1 into a state where it seeks commands at reduced intervals.

The data return path 5 of Figure 1 is shown in greater detail in Figure 4. Consumption data from the electricity sensor 1 is supplied as RF data through link 66 to be stored in the RF buffer 64 accessible by a microprocessor 63. The data return path 5 communicates by wire or wirelessly with the PC or router 7 or with the user display unit 4 through link 67. As with the user display 4, the data return path 5 has its own power management unit 61 and may receive power from an internal rechargeable battery or a solar cell or by other means (not shown). The status of the data return path is indicated by another ambient array 65, such as an LED display operated by a driver 62. The data return path 5 communicates with external data processors or other units through a USB or Ethernet driver 60.

In alternative embodiments, the data return path can include means for accessing the global system for mobile communications (GSM), or Bluetooth or Power Line Communications (PLC) or General Packet Radio Service (GPRS) services, or Public Switched Telephone Networks (PSTN) or other infrastructures which may exist in the domestic or business environment, such as cable or satellite television services and their respective control units.

The monitoring apparatus shown schematically in Figure 1 may also include one or more individual appliance sensors, alternatively named as "proxy sockets" in some literature. One example is shown in Figure 5. These individual appliance sensors 70 measure, store and transmit data indicative of the power consumption of the respective appliance, such as a
refrigerator or a heater or a television. A wired or wireless data link 75 is provided between
an RF buffer unit 74 within the appliance sensor, and other parts of the system which rely on
the appliance data, such as the data return path 5 in Figure 1. The AC supply 71 for the
appliance, which may be a wall socket or a cable for example, is fed directly into a voltage
and current measurement circuit 72, in series, so that current and voltage may be measured
directly and the results fed as data to a microprocessor 77. The power supply 71 is also fed
directly to a power storage and management unit 73 for powering the various circuits within
the appliance sensor 70. A real time clock 76 provides a time signal to the microprocessor 77
which communicates interactively with an internal memory 79 powered by the power storage
and management unit 73. An ambient array 80 may provide a display indicative of the status
of the unit, such as whether the current consumption is above a predetermined threshold, and
this ambient array 80 may for example be one or more LEDs, optionally with different
colours. The ambient array 80 is driven by a driver 78, communicating with the
microprocessor 77.

In alternative embodiments; the appliance sensor 70 has an intelligent switching feature for
controlling and managing the power of the respective appliance, for example using data from
the resource and cost management application 12. The appliance sensor may be embedded in
a plug or in an appliance or in a socket or back box. It may communicate by way of power
line communications (PLC), or ELk-485 (formerly RS485), or USB (or USB 2.0) or RS232,
or Ethernet, or the like.

The system of Figure 1 preferably includes an additional display 90, shown in Figure 6,
referred to as a public display. This is mounted typically on an external wall of a house or
business unit, so that it can be viewed by the public. Its purpose is to communicate the energy
savings made by the user at those premises.

The public display unit 90 receives RF data from the sensor unit 1 through link 96 and stores
them in the RF buffer 95 accessible by the internal microprocessor 94. The public display
unit 90 is typically powered by a solar cell 92, i.e. a photovoltaic cell, which supplies a power
storage and management unit 97. A rechargeable battery 91 is also provided, corresponding
to battery 42 of the user display in Figure 3. A display unit 93 is driven with data from the
microprocessor 94, and provides textual and graphical information of interest to the public,
and including the nature of the energy savings for a period of time. It may also include the
logo of the electricity supplier, for advertising purposes.
The public display unit 90 is preferably circular and is mounted in a vertical orientation outside the premises. It may have a temperature and light sensor to provide environmental data indicative of ambient temperature and light level, for analysis in the microprocessor 94.

In an alternative system, the display unit 90 may simply indicate whether power is being used by the customer, or whether the monitoring system is being used by the customer, in which case there is no need for the microprocessor 94.

Alternative examples of the sensor unit 1 will now be described with reference to Figures 7 to 11. In each of these sensor units 1, the power storage and regulation circuitry 104 includes a rechargeable battery which is required to receive a continuous-trickle charge from a current transformer, and to provide periodic discharge to the microprocessor, data storage and transmission system 106. The most suitable type of battery is the sealed lead acid cell, although it is conceivable that the NiMH battery could be used, as it has a higher energy density. In each example, the current transformer (CT) 102 generates power from the electricity supply cable with which it is coupled, using a clamp, such as to provide maximum mutual inductance with the line. It has a high permeability core 103 that saturates, such as constant voltage charging can be used. The number of turns in the transformer 102 is chosen to set the output voltage for maximum power at a level equivalent to the charging voltage of the battery used. There is no capacitive coupling to the cable, and no electrical contact with it.

Accurate metering of domestic electrical power requires measurement of both current and voltage wave forms of the supply, at a sample rate sufficient to capture all the harmonics carrying significant electrical power. With the use of increasing amounts of low voltage electronic equipment, power may be carried up to the 40th harmonic, necessitating sample rates of the order of kilohertz. However, the power requirements, and the absence of a voltage waveform, in the preferred embodiments of the invention, dictate the need for compromise in the accuracy of the measurements taken. The typical variation in mains supply voltage is 230 volts ± 10% / - 14%, so an assumption of constant voltage will give this order of magnitude of error in the power consumption, which is derived solely from measuring current. Current may be sampled instantaneously, or else by averaging over a sampling period, to produce an integrated charge, measured in Amp hours or Coulombs.

The example shown in Figure 7 has separate current transformers: a power CT 102(1) and a measurement CT 102(2). The power CT 102(1) provides a trickle charge to the power storage
and regulation circuit 104 which drives the microprocessor 106. Current output from the measurement CT 102(2) is instantaneously sampled. The CTs 102(1)-102(2) are made on separate cores 103(1)-103(2), for the best accuracy in measurement.

A circuit with just one CT 102 is shown in Figure 8. This separates this output over two halves of the AC cycle, using rectifying diodes 105(I)-105(4) as shown. This has the benefit of simplicity with only one transformer 102, but the disadvantage of halving the amount of energy available for powering the unit, and the presence of two diode drops.

The alternative circuit shown in Figure 9 provides time multiplexing between power and measurement. Provided instantaneous samples of the current usage are required, this system can be used. The single CT 102 coil is switched alternately between the power supply circuit 104 and the current measurement circuit 106.

In the further alternative circuit shown in Figure 10, battery charge current is measured to monitor the line current. Given the assumption that the electrical properties of the rechargeable battery do not change significantly as it is charged, current in the line, i.e. the mains supply cable to which the unit is clamped, may be determined by measuring the current delivered to the battery from the CT 102. The voltage across a shunt resistor 108, in line with the battery charger circuit 104, is sampled by the microprocessor 106 to deduce current. The current delivered to the load 108 at a constant voltage does not vary linearly with the line current, but rather as the square root of the line current. Thus additional computation is required in the microprocessor 106 to derive current from the measured data.

A further example is shown in Figure 11, which is a metered battery charger. Capacitors HO(I)-1 10(2) at the output of a rectifier 105 are charged by the CT 102. When they reach a voltage that is a predetermined amount above the battery voltage, a comparator 112 switches the capacitors HO(I)-1 10(2) to dump charge into the battery 116. Hysteresis is included in the comparator 112 such that the switch 114 is only open again when the voltage across it, and hence the current flowing from the capacitor 110(1) or 110(2) to the battery 116, is O. By assuming that the amount of charge delivered to the battery is equal for each of these cycles, the total charge delivered by the CT can be monitored by counting the number of cycles in the microprocessor 106. The charge delivered can then be used to derive a measurement of line current. Alternative circuits may use more sophisticated step up/down switch mode power supplies.
This circuit shown in Figure 11 has the advantage of providing an integrated measure of line current, rather than instantaneous samples, and of using a single coil for continuous battery charging and current measurement.

The outputs from the appliance sensors 70 in the system enable the data processors to construct appliance level resource usage patterns, by identifying individual appliances at a system level and allowing deeper analysis of energy usage patterns. The system can infer usage patterns, giving a greater understanding appliance use and mode frequency and hitherto. This level of detail increases the likelihood that a customer will use the system, since it encourages them to collect the richer data and to use the more detailed consumption and energy saving information. Further, the use of the appliance sensors enables intelligent switching of appliances, for control and power management. The system with the appliance sensors builds an energy use profile of individual appliances which can continue to be used even when the appliance sensor has been moved to another appliance. By connecting the voltage and current measurement unit in series with the AC supply, both voltage and current are measured, and this provides an accurate indication of power consumption at the appliance level, data on power consumption from all the appliances in the house can then be accumulated to provide corrections to the integrated consumption data provided by the sensor unit 1, which does not necessarily have the benefit of a voltage measurement.

As was described previously, with existing clamp-on meters the changing of the battery is not the preferred option due to the inaccessibility of the device when installed in a meter cupboard. Also the user can be exposed to more interaction with mains wiring. In order to avoid changing the battery and its perceived difficulties, embodiments of clamp-on energy meters according this invention can obtain, by use of a current transformer, the energy for circuitry operation from the supply being monitored using a current transformer.

Figure 12 depicts a diagrammatic perspective view of an embodiment a clamp-on energy meter 120 coupled to a power line 121, in accordance with the present invention. Figure 13 is a diagrammatic side view with circuit diagram of an embodiment similar to that shown in Figure 12.

As shown in Figures 12 and 13, a clamp-on energy meter 120 according to the present invention can include a C-shaped clamp section 122, e.g., as adapted to fit around a power cable, and a body 124. The clamp section 122 can include a magnetic core 126, which can be
surrounded by insulating material 128. A coil 130 can be configured around the core 126. Any suitable material can be used for the magnetic core 126. Examples include, but are not limited to, soft iron, laminated silicon steel, carbonyl iron, and ferrite ceramics. As noted, a hinge or equivalent feature can be utilized to allow placement of the clamp section around a wire/line.

The body 124 can include an electronics block/circuitry 132 that is operational for metering (measuring) and energy harvesting (storing) applications. The electronic block/circuitry 132 can be connected to the coil 130, as depicted in the drawing, by suitable connections. The clamp section 122 can be bendable and/or have a hinge functionality, e.g., as indicated by hinge joint 134 and end gap 136, so as to facilitate application around a power line, e.g., line 121 of Figure 12.

In operation, current transformer 130 steps down the current it is monitoring by a fixed ratio. The resultant current on its coil (130) can then measured by a precision burden resistor, e.g., in electronics block/circuitry 132. This burden resistor has a low resistance in order to make accurate current measurements. Energy harvesting requires a higher resistance across the coil 130 in order to generate a high enough voltage to run the circuitry. Switching between the two circuit functionalities can be achieved by electrically isolating the burden resistance (resistor) when energy harvesting is being performed. When the burden resistor is connected with the voltage across the coil drops and the harvesting circuitry ceases to operate. Exemplary embodiments of the present invention can incorporate both these actions into a clamp-on meter, e.g., as shown in Figure 13.

Exemplary embodiments of such clamp-on energy meters according to the present invention can use the same current transformer, e.g., coil 130, for both metering and energy harvesting applications to enable the devices to be handheld and low-cost.

Figure 14 is a schematic block diagram of an embodiment of a clamp-on energy meter 120 similar to those shown in Figures 12 and 13. The clamp-on energy meter 120 can include a clamp section 122 which can be connected to an electronics block/circuitry 132 by way of electrical connection 141 and a current transformer, e.g., coil 130. The electronics block/circuitry 132 can include a switching circuit 142, and a current metering or measurement circuit 143. The electronics block/circuitry can also include an energy harvesting circuit 144 and an energy storage device/circuit 145, examples of which include a
rechargeable battery, a capacitive circuit (e.g., including one or more sufficient capacitors), and the like. The switching circuit 142 can switch the current from the current transformer to either the current metering circuit 143 or the energy harvesting circuit 144, depending on the operation required or as needed.

The energy meter 120 accordingly switches, by way of switching circuit 142, between harvesting energy and metering (or measuring) the supply current, while utilizing the same current transformer 130 for each function. As described previously, this can be achieved by electrically isolating the burden resistance (resistor) when energy harvesting is being performed. When the burden resistor is connected with the voltage across the coil drops and the harvesting circuitry ceases to operate.

In operation of energy meter 120, as the metered supply is changing and sometimes there is little or no current flowing, the energy harvesting requires some energy storage to maintain power to the circuitry at all times. As the supply current is generally low for a metered end user the energy available to harvest is low. Therefore the device circuitry is preferably very low in power for exemplary embodiments.

One skilled in the art will appreciate that the energy meters shown and described for Figures 12-14 can be utilized alone, or they may be used in conjunction with other embodiments shown and described herein, e.g., for Figures 1-11.

Accordingly, relative to prior art technique, the clamp-on metering devices according to the present invention do not require battery changing, and provide advantages of safety and convenience. Minimized cost can be achieved by using the same current transformer for both metering and energy harvesting. Additionally, clamp-on metering devices according the present invention an be a handheld device due to use of a single current transformer. These metering devices can also operate from an intermittent metered supply due to the included energy storage component.

It will be appreciated that the invention is not limited to the examples shown here. For example, other methods of communication and of display can be used, and the data processing within the entire system can be located at any convenient point, whether by the meter or in another unit such as a display, or elsewhere using the Internet. It will be understood that this system, in its preferred embodiment, is particularly reliable with minimum maintenance, through the use of electrical power from the mains power supply
itself and/or from rechargeable batteries or solar cells. Consumption data are stored reliably
in memory which is protected from tampering or damage, and from confusion with any data
relating to other consumers. The sensor unit is intended to be fitted just once and to last for
several years without the need for maintenance. The use of communications networks allows
the software in the system to be updated from time to time without direct intervention.
CLAIMS:

1. Apparatus for monitoring the consumption of electricity supplied on a cable, comprising:

   an electricity sensor unit having a current transformer housed in an electrically-insulative housing clampable over the cable to form an inductive, non-conductive coupling between the or each current transformer and the cable;

   the sensor unit comprising:

   an energy storage circuit configured and arranged to be coupled to the current transformer and to supply power for the sensor unit;

   a current measurement circuit configured and arranged to be coupled to the current transformer and powered from the energy storage circuit or the current transformer and responsive to current induced in the current transformer to provide an output signal representative of the current that has flowed on the cable over a period of time; and

   a switching circuit connected to the current transformer and the energy storage circuit and the current measurement circuit, the switching circuit being configured and arranged to switch current from the current transformer to the energy storage circuit by isolating a burden resistance and to alternatively switch current from the current transformer to the current measurement circuit by connecting the burden resistance to the current transformer.

2. Apparatus according to Claim 1, wherein the burden resistance comprises a burden resistor.

3. Apparatus according to Claim 1, wherein the electricity sensor comprises a clamp section adapted for configuration around a power cable.

4. Apparatus according to Claim 1, wherein the clamp section comprises a magnetic core and wherein the current transformer includes a coil configured around a portion of the magnetic core.

5. Apparatus according to Claim 4, wherein the clamp section comprises a hinge.
6. Apparatus according to Claim 1, further comprising a data communication circuit powered from the energy storage circuit and responsive to the output signal to transmit data representative of the output signal to an external receiver.

7. Apparatus according to Claim 1, further comprising a display unit configured and arranged to display an indication of the measured current.

8. Apparatus according to Claim 7, in which the display unit comprises a rechargeable internal battery.

9. Apparatus according to Claim 7, in which the display unit comprises a solar power panel arranged to power the display unit and/or to recharge the internal battery.

10. Apparatus according to Claim 7, in which the display unit comprises a display screen and a data processor arranged to display text and/or graphics on the screen relating to the consumption of electricity.

11. Apparatus according to any of claims 7-10, in which the display unit comprises a light-emitting display and a driver for controlling that display to indicate the status of the apparatus.

12. Apparatus according to Claim 1, in which the energy storage circuit comprises an energy store including a rechargeable battery.

13. Apparatus according to Claim 1, in which the energy storage circuit comprises an energy store including a circuit with one or more capacitors.

14. Apparatus according to any preceding claim, further comprising a public display unit, separate from the sensor unit and from any user display unit, but in wired or wireless communication with the sensor unit to display information relating to the consumption of electricity including information derived from the output signal.

15. Apparatus according to Claim 14, in which the apparatus is configured to compute energy savings made as a result of changes to the consumption of electricity on the cable over a period of time, and to display information on the public display unit indicative of those savings.
16. Apparatus according to any preceding claim, comprising a computer network interconnecting the sensor unit with other data processing units for communicating with the user and/or the supplier of the electricity.

17. Apparatus according to Claim 16, in which the computer network is connected to the Internet.

18. Apparatus according to Claim 16 or 17, in which the computer network comprises a data processor configured for customer relationship management between the user and the supplier of the electricity.

19. Apparatus according to Claim 18, in which the data processor of the computer network is configured to receive data representative of the cost of the electricity consumed on the cable.

20. Apparatus according to any preceding claim, arranged to communicate with a smart meter which is connected in series with the cable to measure current consumption.
Fig. 1
Fig. 2
Fig. 3
Fig. 6

Fig. 7
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC

B.walletWelldocumentsearched(classificationsystemfollowedbyclassificationsymbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>column 3, line 59 - column 4, line 15 column 6, line 22 - line 54 column 7, line 26 - line 31</td>
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D. Further documents are listed in the continuation of Box C. See patent family annex.

- Special categories of cited documents:
  - 'A' document defining the general state of the art which is not considered to be of particular relevance
  - 'E' earlier document but published on or after the international filing date
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Date of the actual completion of the international search: 29 August 2008

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