

Electricity Meter with Isolated Shunt

Field of Invention

The present invention relates to electricity metering and more particularly to an
5 electricity meter using a voltage transformer isolated shunt.

Background

An electricity meter can measure the amount of electricity consumed by a consumer
such as a residence, business or electrical device. Typically, consumers are charged
10 on a 'per unit' basis, so it is important that the meter is able to accurately determine
how much electricity the consumer has consumed over a particular time period.
Inaccuracies in the measurements made by the meter can translate into overcharging
or undercharging a consumer. Additionally, accurate data on the amount of electricity
consumed may be valuable to an electricity provider.

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Typically one of current shunts or current transformers can be used as current sensors
in electricity meters. Current transformers exhibit non-linear behaviour as a function of
load current and are affected by external magnetic fields. Variations of this kind can
lead to errors in the current consumption calculated by an electricity meter making use
20 of a current transformer as a current sensor. Shunts tend to behave reasonably linearly
as a function of temperature, but do not provide galvanic isolation between the
measurement circuit and the input circuit. Shunts therefore cannot be used in situations
where typically more than one current circuit has to be measured. Temperature is one
factor that can affect the accuracy of data that is output by an electricity meter using
25 either of current sensor or shunt. In particular, the temperature of electromagnetic
components and windings within the meter may adversely affect the accuracy of meter
readings.

Electricity meters are typically installed on-site where space is often at premium. For
30 example, in the case of a private residence, an electricity meter will typically be
provided within the residence itself. It is usually preferred to locate the meter
somewhere where it is accessible but will not be visible day-to-day, e.g. in a cupboard
or the like, both for aesthetics and also for safety reasons. Sometimes a large number

of meters are installed in a relatively small space such as in apartment blocks. To assist with this, it is desirable that the size of the meter is kept to a minimum. It is also desirable that an electricity meter is tamper-proof to prevent the accuracy of the data that the meter outputs being accidentally or deliberately compromised.

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Summary of the Invention

From a first aspect the present invention provides an electricity meter according to the appended independent claim 1.

10 From a second aspect the present invention provides a method of determining an amount of electricity consumed according to appended independent claim 15.

Further preferable aspects are provided in the appended dependent claims.

15 The invention provides an electricity meter that makes use of a current measurement device comprising a shunt in combination with an isolating voltage transformer. The shunt is electrically connected to a supply circuit and the primary windings of the isolating voltage transformer are electrically connected to first and second ends of the shunt. The secondary windings of the voltage transformer are coupled to a control
20 device, which may be a microcontroller. The control device measures a voltage developed in the secondary windings of the transformer and uses this voltage to estimate a power consumption of a load carrying the supply current. This arrangement provides galvanic isolation between the supply circuit and the measurement circuit.

25 In preferred embodiments, a temperature sensor is provided to measure the temperature of the voltage transformer. This allows the voltage measured by the control device to be corrected for temperature variations of the measurement circuit and particularly in the windings or core of the voltage transformer. The temperature sensor may be integrated with the control device, or it may be external to the control
30 device. In the case that the temperature sensor is external to the control device, it is preferably mounted near the core of the voltage transformer.

Brief Description of the Drawings

Embodiments of the invention are described below in more detail, by way of example, with reference to the accompanying drawings in which:

- 5 Figure 1 shows a perspective view of an electricity meter according to an embodiment of the invention;

Figure 2 shows a perspective view of the meter of Figure 1 with the bottom cover open;

- 10 Figure 3 shows another perspective view of the meter of Figure 1 with the bottom cover open with the input and output terminals shown;

Figure 4 shows a perspective view of a part of the meter shown in Figure 1;

- 15 Figure 4A is a top view of Figure 4;

Figure 4B is a side view of Figure 4;

Figure 4C is a front view of Figure 4;

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Figure 5 is an exploded perspective view of a transformer that is installed in the meter of Figure 1;

- Figure 6 is a circuit diagram of a current measuring circuit showing a shunt connected
25 to a control circuit through the transformer of Figure 5; and

Figure 7 is a flowchart showing the operation of a control device that is included in the meter of Figure 1.

30 Detailed Description of Embodiments

The invention is described in the following with reference to Figs. 1 to 6, which show an embodiment of an electricity meter which is a modern electronic meter utilising a shunt

in the neutral circuit in order to detect consumption of electricity. As will be described, the shunt is galvanically isolated using a voltage transformer.

Electricity meter 10 comprises a housing including a base 11 and a top cover 12. The
5 base 11 and cover 12 are formed of plastics material but may be formed of other material that is preferably electrically insulating.

In this embodiment, electricity meter 10 is a single phase meter and includes a terminal block section integrated with the base 11 with two live terminals 13a, 13b and two
10 neutral terminals 14a, 14b. In this embodiment the terminals are made of brass, but other suitable materials known to the skilled person can be used instead. Where the source of electricity is a polyphase source, preferably live terminals 13a, 13b are connected to only a single phase of the polyphase source. The terminals 13a and 14a are connected to the live and neutral connections respectively to the supply side of a
15 source of electricity (e.g. a national electricity grid) and the terminals 13b, 14b are connected the live and neutral connections respectively of the consumer side of the meter (e.g. the internal electrical network of the site at which meter 10 is located). It will be appreciated that more or less terminals may be provided. In particular, single ports may be provided or more than two ports can be provided.

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A bottom cover 15 is located at the bottom of the housing and can be attached to the top cover 12 such that the terminals are at least partially covered. The bottom cover 15 can be opened as shown in Figs. 2 and 3 which enables access to the terminals and, in this embodiment, this is achieved with two hinged portions 15a that are located on the
25 front of the bottom cover 15 and are received in cooperating elements 15b in the cover 12. An exposed section 16 is provided in the bottom cover 15 to enable cables or other connections means (not shown) to pass from the outside of the meter housing to the terminals 13a, 13b, 14a and 14b. A display 17 may be provided in a front face of electricity meter 10 to allow a user to monitor the status of the meter. Some form of
30 user interface device, e.g. one or more buttons or the like may be provided in one or more faces of electricity meter 10 in order to allow a user to interact with and control the meter.

Electricity meter 10 also includes an electricity consumption monitoring device 400 that monitors the consumption of electricity, as shown schematically in Fig. 4. Electricity consumption monitoring device 400 includes a shunt 19, an isolating voltage transformer 401 (shown in detail in Figs. 5 and 6) and a control device 402. In the
5 illustrated embodiment shunt 19 is connected across neutral terminals 14a and 14b to allow the neutral current to flow through it. A shunt configured in this way is adapted to measure the neutral current. However, in an alternative embodiment, shunt 19 is connected across live terminals 13a and 13b. In that case, the live current flows through shunt 19 and is measured. Control device 402 is electrically coupled to voltage
10 transformer 401 by a pair of conductors 403a, 403b, which in the illustrated embodiment are electrical wires. Other suitable electrically conductive elements known to the skilled person can be used instead. In one embodiment, control device 402 is a microcontroller.

15 In a preferred embodiment control device 402 includes an integrated temperature sensor (not shown) that is located within control device 402. The temperature sensor determines the temperature of transformer 401 as discussed later in connection with Fig. 8. In an alternative embodiment the temperature sensor is not integrated with control device 402 and is instead located external to control device 402, and is
20 preferably mounted on transformer 401.

As shown in Figs. 4 and 6, electricity consumption monitoring device 400 is electrically connected across the terminals 14a and 14b via shunt 19. In another non-illustrated embodiment, electricity consumption monitoring device 400 is electrically connected
25 across other terminals e.g. terminals 13a and 13b via shunt 19. The isolating voltage transformer 401 is electrically connected to one end of the shunt pick off by a first conductor 404a and electrically connected to another end of the shunt pick off by a second conductor 404b. In the illustrated embodiment the first and second conductors are electrical wires, preferably copper wires, but other suitable electrically conductive
30 elements known to the skilled person can be used instead. It will be appreciated that, in Fig. 4, elements of meter 10 that are not essential to the understanding of the working of this aspect of the invention have been omitted, for ease of understanding. For

example, it will be appreciated that meter 10 may also be connected to a live circuit via terminals 13a, 13b. This connection is omitted from Fig. 4 in the interests of clarity.

First and second conductors 404a, 404b are each secured in a respective one of
5 terminals 14a, 14b via shunt 19. Specifically, first conductor 404a is connected to one terminal of shunt 19 and second conductor 404b is connected to another terminal of shunt 19. Conductors 404a, 404b can be connected to shunt 19 by any suitable securing means known to the skilled person that allows for electrical coupling between the conductors and the shunt. In the present embodiment, conductors 404a, 404b are
10 connected directly to shunt 19 by soldering.

The shunt itself is electrically connected to at least one bus bar (not shown). Preferably the shunt is connected to a plurality of copper bus bars. The shunt is preferably connected to the at least one bus bar by welding, but other connection means known to
15 the skilled person and capable of providing an electrical coupling between shunt 19 and the at least one bus bar can be used instead. In turn, the at least one bus bar is electrically connected to terminal 14a and terminal 14b. The at least one bus bar is preferably welded to each of terminals 14a, 14b, but in an alternative embodiment the at least one bus bar is screwed to each of terminals 14a, 14b. Other suitable
20 connection means that provide an electrical coupling between the at least one bus bar and terminals 14a, 14b that are known to the skilled person can be used instead.

As best shown in Fig. 4, meter 10 includes four screws 18a, 18b, 18c and 18d, with two screws being located on each of terminals 14a, 14b. These screws provide a
25 mechanism for electrically connecting each terminal to a mains supply, e.g. a national power grid, and specifically connecting each terminal to wires coupled to the mains supply. It will be appreciated that any securing means known to the skilled person that is capable of securing terminals 14a, 14b to a mains supply can be used instead of screws.

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Fig. 5 shows a schematic exploded view of voltage transformer 401. Voltage transformer 401 includes a casing 600. In the illustrated embodiment casing 600 is generally cylindrical and comprises a generally circularly shaped lid portion 601 and a

corresponding generally cylindrical housing 602. In use, lid portion 601 is secured onto an end face 603 of housing 602 to provide a hollow enclosure in which the other parts of voltage transformer 401 reside. It will be appreciated that it is not essential that casing 600 be generally cylindrical, and differently shaped casings are also contemplated e.g. cuboidal, etc. Preferably the shape of casing 600 is chosen to co-operate with and suitably accommodate the electrical components of voltage transformer 401.

The function of casing 600 is to provide a sturdy, tamper-proof housing that encloses the internal electrical components of voltage transformer 401. Preferably casing 600 is made of metal, and more preferably casing 600 is made of a metal that effectively shields against external magnetic fields. In one embodiment, casing 600 is made of low carbon extra-deep-drawing (EDD) grade steel.

In the illustrated embodiment, lid portion 601 includes a generally circular access hole in its surface. This shape is not essential and other shapes of hole, e.g. square or rectangular, can alternatively be used. The access hole is provided to allow conductors 404a, 404b to access the interior of voltage transformer 401. Similarly, another access hole (not shown) is provided in casing 600 to allow conductors 403a, 403b to access the interior of voltage transformer 401. It will be appreciated that these access holes can be replaced with any mechanism known to the skilled person that allows a conductor (e.g. a wire) to access the interior of casing 600.

In the illustrated embodiment lid portion 601 also includes an optional pair of indentations 604a, 604b. These are provided at opposing points around the perimeter of lid portion 601. These indentations are provided to allow a tool to be used to open lid portion 601 when required. Embodiments that omit these indentations, or provide indentations at different locations and/or different numbers of indentations are also contemplated.

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A wound transformer core 605 is located in the interior of casing 600. Wound core 605 comprises a transformer core wound with at least one turn of wire, which is preferably copper wire. Wound core 605 is mounted on a mount 606 that is also located in the

interior of casing 600. Mount 606 includes a protrusion 607 that fits snugly into the air gap 608 of wound core 605, so as to hold wound core 605 in place. In some embodiments, wound core 605 is coated in an epoxy. In other embodiments, wound core 605 is encapsulated within mount 606.

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The transformer core is made of any suitable material known to the skilled person to be suitable for the operation of a voltage transformer, such as nano-crystalline steel, silicon steel or ferrite. Mount 606 is made of an electrically insulative material such as a plastic.

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In the illustrated embodiment the transformer core is toroidal, but it will be appreciated that other shapes, e.g. rectangular or square, can alternatively be used. The shape of the transformer core, mount 606 and protrusion 607 is not critical, but should be chosen such that the elements co-operate with one another so as to hold the
15 transformer core securely in place.

Electrical conductors are wrapped around the transformer core to form primary and secondary windings, as is common in the art of transformer design. Preferably an electrically insulating material is provided between the transformer windings and casing
20 600, to prevent a flow of electrical current both from the windings to casing 600 and also between adjacent windings. The electrical insulation can be of any type known to the skilled person, such as insulation tape, Mylar® tape as manufactured by DuPont™, an epoxy or an electrically insulative sheath such as a silicon rubber sleeve or a PVC sleeve. Advantageously, mount 606 and protrusion 607 serve to electrically insulate the
25 transformer core from its exterior, including lid portion 601 and housing 602.

It will be appreciated by one skilled in the art that many aspects of the design and construction of casing 600, wound core 605 including the transformer core itself and/or the windings, and mount 606 can be varied according to the specifics of the situation at
30 hand. What is important is that the resulting arrangement can provide an electrical circuit as shown in Fig. 6, as discussed immediately below. Additionally, the resulting arrangement should meet any national standards that apply to electricity meters. For

example, in the UK, transformer 401 is designed such that it conforms to IEC 62052-11 and IEC 62053-21.

Further, the specification of the transformer is preferably such that it provides high
5 linearity over a wide voltage input range of 10,000x. In the illustrated embodiment, this voltage input range corresponds to the drop across shunt 19 for currents ranging from 10 mA to 100 A.

Fig. 6 is a circuit diagram of electricity consumption monitoring device 400 that is
10 shown in Fig. 4. Shunt 19 is connected directly across the measuring circuit terminals 14a and 14b. Shunt 19 is made of a low temperature coefficient of resistance material such as Manganin™. Shunt 19 is designed to carry almost the entire current through it thereby producing a voltage drop across the shunt. Isolating transformer 401 picks off this voltage drop as described in the following.

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As is known in the art, the transformer core comprises primary windings and secondary windings. As shown in Fig. 6, primary windings 701 are electrically connected across the shunt 702 via wires 404a, 404b. Shunt 19 can be electrically connected to conductors 404a, 404b via any suitable technique known to the skilled person, such as
20 electron beam welding, brazing, screwing, etc. Secondary windings 703 are electrically connected to the control device 402 via conductors 403a, 403b such that the induced secondary voltage across secondary windings 703 is fed to control device 402.

Shunt 19 can be any suitable piece of electrically conductive material with high resistive
25 stability. In one embodiment shunt 19 is a piece of Manganin™ bar welded to at least one copper bus bar. Other suitable materials for shunt 19 will be selected by the skilled person having the benefit of the teaching herein. The resistance R of shunt 19 is controlled according to the material that shunt 19 is made of, as well as the dimensions of the piece or pieces of that material which are used in shunt 19. A person skilled in
30 the art will be able to select a desired resistance by varying these parameters suitably.

In operation, current from the source flows through shunt 19 via terminals 14a, 14b.. Shunt 19 has a resistance R which causes a voltage to develop across the terminals of

shunt 19. Preferably the resistance R is low so that shunt 19 does not consume significant power, since any power consumed by shunt 19 is wasted as it is not being supplied to the consumer. More preferably, shunt 19 has a resistance R that is chosen based on requirements of temperature rise, power loss and transformer linear
5 operating range. These requirements may be set by various standards.

Additionally, a low resistance means that the voltage developed across the terminals of shunt 19, which is also the voltage across primary windings 701, is small. This in turn means that the voltage applied across the primary windings 701 is small. This
10 advantageously allows the transformer core to be smaller than would otherwise be the case. This reduction in size advantageously translates into both a reduction in size of meter 10 and also a reduction in the manufacturing costs of meter 10. These advantages are realised by the combination of voltage transformer 401 and shunt 19 as described above and shown in Fig. 6. For a given current, this combination results in a
15 smaller electrical consumption monitoring circuit than a conventional electrical consumption monitoring circuit such as a circuit including a current transformer.

The voltage across the terminals of shunt 19 is in turn developed across primary windings 701 of the transformer, which in turn generates a voltage across secondary
20 windings 703 in the manner well known in the art of transformer design. The magnitude of the voltage across secondary windings 703 can be controlled by adjusting the number of turns of the primary and/or secondary windings, as is known in the art, as well as by adjusting the resistance R of shunt 19. Other parameters that may be adjusted include: the gauge of the wire used to form the windings and the winding
25 method. Preferably the above-discussed parameters are adjusted to achieve good performance for long current range.

The voltage across secondary windings 703 is measured at an input of control device 402. Control device 402 measures the amplitude and optionally the phase of this
30 voltage as a function of time. This raw data is processed by control device 402 to determine the current that is being consumed. This determination of current consumption may be one of the outputs of meter 10. The current measurement may be further processed to determine various other electrical parameters such as energy

consumed or generated, reactive energy, power, power factor, etc. Control device 402 preferably includes or is communicatively coupled to a storage device such as a non-volatile memory card or the like, to allow control device 402 to store the electricity consumption data that it has generated. The raw voltage data as measured at the input
5 of control device 402 may also be stored, if desired. Any other data that is gathered or generated by control device 402 and that is considered useful by the skilled person can also be stored. Control device 402 may be coupled to an external network, e.g. the internet, in order to allow the raw voltage data and/or the electricity consumption data to be transmitted to a remote location for storage and/or further analysis.

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The arrangement of shunt 19 and voltage transformer 401 is compact and also advantageously provides the required isolation between the input side of meter 10 and the measurement side of meter 10. Specifically, voltage transformer 401 galvanically isolates the measurement side of meter 10 from the input side of meter 10, preventing
15 a short circuit between these circuits. The behavior of shunt 19 that is relevant to the current consumption measurement is largely temperature independent, meaning that the current consumption estimate obtained by meter 10 is highly accurate even without temperature correction. This is in contrast to an arrangement in which a current transformer is used to measure a current consumption, where significant temperature-
20 related errors are encountered.

Despite the use of shunt 19, it is recognised that temperature-induced errors can arise from heating of voltage transformer 401. While these errors are not as significant as would be expected if a current transformer alone was used instead of the shunt, they
25 are nevertheless preferably corrected for. This is because the proximity of voltage transformer 401 to shunt 19 coupled with the small size of the transformer core, means that in use the transformer core and its winding tend to heat up to significant temperatures. Here, significant temperatures are temperatures of a level that introduces errors of a magnitude large enough to warrant correction in the current
30 measured by control device 402.

Specifically, heating of the transformer introduces ratio / phase error in the measured current. One way of addressing this problem is to use a large voltage transformer with

lower resistance windings made of thicker copper wires. However, as noted above, preferably voltage transformer 401 is as small as possible and so increasing the size of the transformer is counterproductive. Therefore, in order to address this source of error, in preferred embodiments control device 402 is also configured to correct for
5 temperature fluctuations of voltage transformer 401.

The processing performed by control device 402 is shown in Fig. 7. In step 800, the control device measures a secondary voltage (i.e. the voltage induced in secondary windings 703) at an input. Following this, in step 801 the control device measures one
10 or more parameters associated with the measured voltage. The measured parameters include the amplitude of the measured voltage and may include the phase of the measured voltage, as well as any other parameter of interest.

Steps 800 and 801 may be repeatedly carried out for some time period in order to build
15 up a dataset that represents the measured voltage as a function of time. The remaining steps of the processing shown in Fig. 7 can then be carried out on the dataset. This may be referred to as 'near real-time processing'. Alternatively, steps 802 and 803 may be carried out immediately after step 801, with the entire process of steps 800 to 803 then being repeated. This may be referred to as 'real-time processing'.

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In step 802 the control device processes the corrected measurements to determine an electricity consumption. The processing of voltage and current measurements in order to determine an electricity consumption is well known in the art and as such details are not provided here. In step 803 the determined electricity consumption is logged in a
25 suitable storage device which, as discussed earlier, could be a non-volatile memory card. Transmission of data to a remote location for storage via a network is also contemplated. The logged electricity consumption data gives an indication of how much electricity a load, e.g. a residential ring circuit, has consumed in a given time period.

30 In preferred embodiments, control device 402 is configured to apply a temperature correction to the parameters measured in step 801. The applied temperature correction takes account of and compensates for the temperature of voltage transformer 401 and in particular the transformer core and windings.

It will be appreciated that the temperature of voltage transformer 401 will vary as a function of time and in a relatively unpredictable manner. It is therefore not possible to apply a predetermined, static correction factor. Instead, in preferred embodiments
5 control device 402 is configured to apply a ratio or phase error correction factor based on the current temperature of transformer 401. The temperature of transformer 401 is determined by a temperature sensor that may be integrated with control device 402, or may be external to control device 402. The location of an external temperature sensor is preferably chosen so that it is able to make accurate measurements of the
10 temperature of transformer 401 and particularly the transformer core and windings.

Numerous modifications, adaptations and variations to the embodiments described herein will become apparent to a person skilled in the art having the benefit of the present disclosure, and such modifications, adaptations and variations are also
15 embodiments of the present invention.

Claims

1. An electricity meter, comprising:
a voltage transformer having a core comprising primary windings and secondary
5 windings;
a shunt having first and second shunt terminals; and
a control device configured to determine a current consumption;
wherein:
a first end of the primary windings of the voltage transformer core is coupled to
10 the first shunt terminal, and a second end of the primary windings of the voltage
transformer core is coupled to the second shunt terminal;
the secondary windings of the voltage transformer core are coupled to an input
of the control device to provide a voltage for measurement by the control device; and
the control device is further configured to apply a correction to the voltage for
15 measurement by the control device, wherein the correction is based on a temperature
of the voltage transformer.
2. The electricity meter of claim 1, wherein the first shunt terminal is configured to
be electrically coupled to an electrical connection on a supply side of a source of
20 electricity and the second shunt terminal is configured to be electrically coupled to an
electrical connection on a consumer side of the electricity meter.
3. The electricity meter of claim 2, wherein the supply side electrical connection
and the consumer side electrical connection are both one of live and neutral
25 connections.
4. The electricity meter of any preceding claim, further comprising a casing made of
a material having a high magnetic saturation flux density so that the casing acts as a
magnetic shield, wherein at least the voltage transformer is located within the casing.
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5. The electricity meter of claim 4, wherein the casing is made of low carbon extra-
deep-drawing steel.

6. The electricity meter of any preceding claim, wherein the shunt comprises a bar comprising a low temperature coefficient of resistance material.
7. The electricity meter of any preceding claim, wherein the shunt is made of an alloy of copper, manganese and nickel.
8. The electricity meter of claim 6 or claim 7, wherein the shunt comprises a bar welded to at least one copper bus bar.
9. The electricity meter of any preceding claim, wherein the control device includes an integrated temperature sensor.
10. The electricity meter of any one of claims 1 to 8, further comprising a temperature sensor located proximate the voltage transformer, the temperature sensor coupled to the control device and configured to provide temperature information to the control device.
11. The electricity meter of any one of claims 1 to 11, wherein the control device is configured to:
- measure at least one parameter associated with the voltage at the input of the control device;
 - apply a temperature correction to the at least one parameter to determine a temperature corrected voltage; and
 - determine an electricity consumption based on the temperature corrected voltage.
12. The electricity meter of claim 11, wherein the at least one parameter includes an amplitude of the measured voltage.
13. The electricity meter of claim 12, wherein the at least one parameter further includes a phase of the measured voltage.

14. The electricity meter of any preceding claim, wherein the control device comprises a microcontroller.
15. A method of determining an amount of electricity consumed, comprising:
5 providing an electricity meter, the electricity meter comprising:
a control device configured to determine a current consumption;
a shunt having a first shunt terminal and a second shunt terminal; and
a voltage transformer having a core comprising primary windings and secondary
windings, wherein a first end of the primary windings is coupled to the first shunt
10 terminal, a second end of the primary windings is coupled to a second end of the shunt
terminal, and the secondary windings are coupled to the control device;
coupling the electricity meter to a first terminal on a supply side of the electricity
meter,
coupling the electricity meter to a second terminal on a consumer side of the
15 electricity meter;
measuring a voltage generated in the secondary windings of the voltage
transformer using the control device;
applying a temperature correction to the measured voltage to produce a
temperature corrected voltage; and
20 determining a current consumption based on the temperature corrected voltage.
16. The method of claim 15, wherein the first shunt terminal is configured to be
electrically coupled to the first terminal and the second shunt terminal is configured to
be electrically coupled to the second terminal.
- 25 17. The method of claim 16, wherein the first terminal and the second terminal are
both one of live connections and neutral connections.
18. The method of claim 15, wherein the step of applying a temperature correction
30 to the measured voltage to produce a temperature corrected voltage further includes
measuring a temperature using a temperature sensor.
19. The method of any one of claims 15 to 18, further comprising:

measuring at least one parameter associated with the voltage at the input of the control device;

applying a temperature correction to the at least one parameter to determine a temperature corrected voltage; and

5 determining an electricity consumption based on the temperature corrected voltage.

20. The method of any one of claims 15 to 19, wherein at least the voltage transformer is housed in a casing made of a material having a high magnetic saturation
10 flux density so that the casing acts as a magnetic shield.

21. The method of claim 20, wherein the casing is made of a low carbon extra-deep-drawn steel.

15 22. The method of any one of claims 15 to 21, wherein the shunt comprises a bar comprising a low temperature coefficient of resistance material.

23. The method of any one of claims 15 to 22, wherein the shunt is made of an alloy of copper, manganese and nickel.

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24. The method of claim 22 or claim 23, wherein the shunt comprises a bar welded to at least one copper bus bar.

25. The method of any one of claims 15 to 24, wherein the measuring a voltage
25 generated in the secondary windings of the voltage transformer comprises measuring at least one parameter associated with the voltage at an input of the control device.

26. The method of claim 25, wherein the at least one parameter includes an amplitude of the measured voltage.

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27. The method of claim 26, wherein the at least one parameter further includes a phase of the measured voltage.

28. The method of any one of claims 15 to 27, wherein the control device comprises a microcontroller.