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(54) **SYSTEM AND METHOD FOR CONTROLLING AN ELECTRICITY SUPPLY**

(71) Applicant: **The Technology Partnership PLC**, Melbourn Royston (GB)

(72) Inventors: **Mathew R. Palmer**, Melbourn Royston (GB); **Antony W. Rix**, Melbourn Royston (GB); **David R. Anderson**, Melbourn Royston (GB); **David S. Smith**, Melbourn Royston (GB); **Matthew C. B. Lumb**, Melbourn Royston (GB)

(73) Assignee: **The Technology Partnership PLC**, Melbourn Royston (GB)

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CPC ***H02J 13/00024*** (2020.01)

(58) **Field of Classification Search**
CPC H02J 3/05
USPC 307/43
See application file for complete search history.

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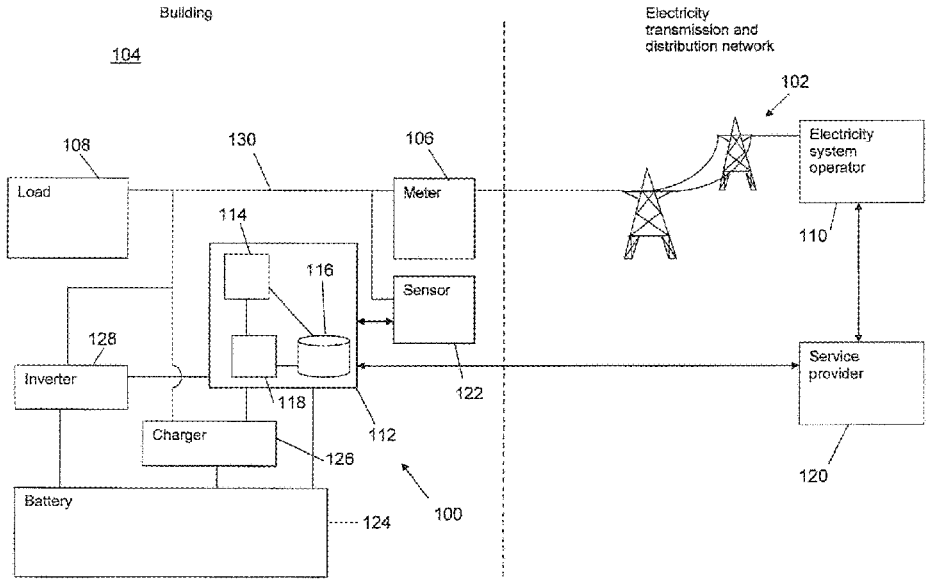
Primary Examiner — Fred O Ferris, III

(57) **ABSTRACT**

A system for controlling an electricity supply to a load comprises at least one battery for storing energy. The system also comprises a controller for determining when to switch between a first mode wherein electricity is supplied to the load from a mains electricity circuit; and a discharging mode wherein electricity is supplied from the battery to the load via the mains electricity circuit. The determining is based on information associated with the electricity supply.

17 Claims, 8 Drawing Sheets



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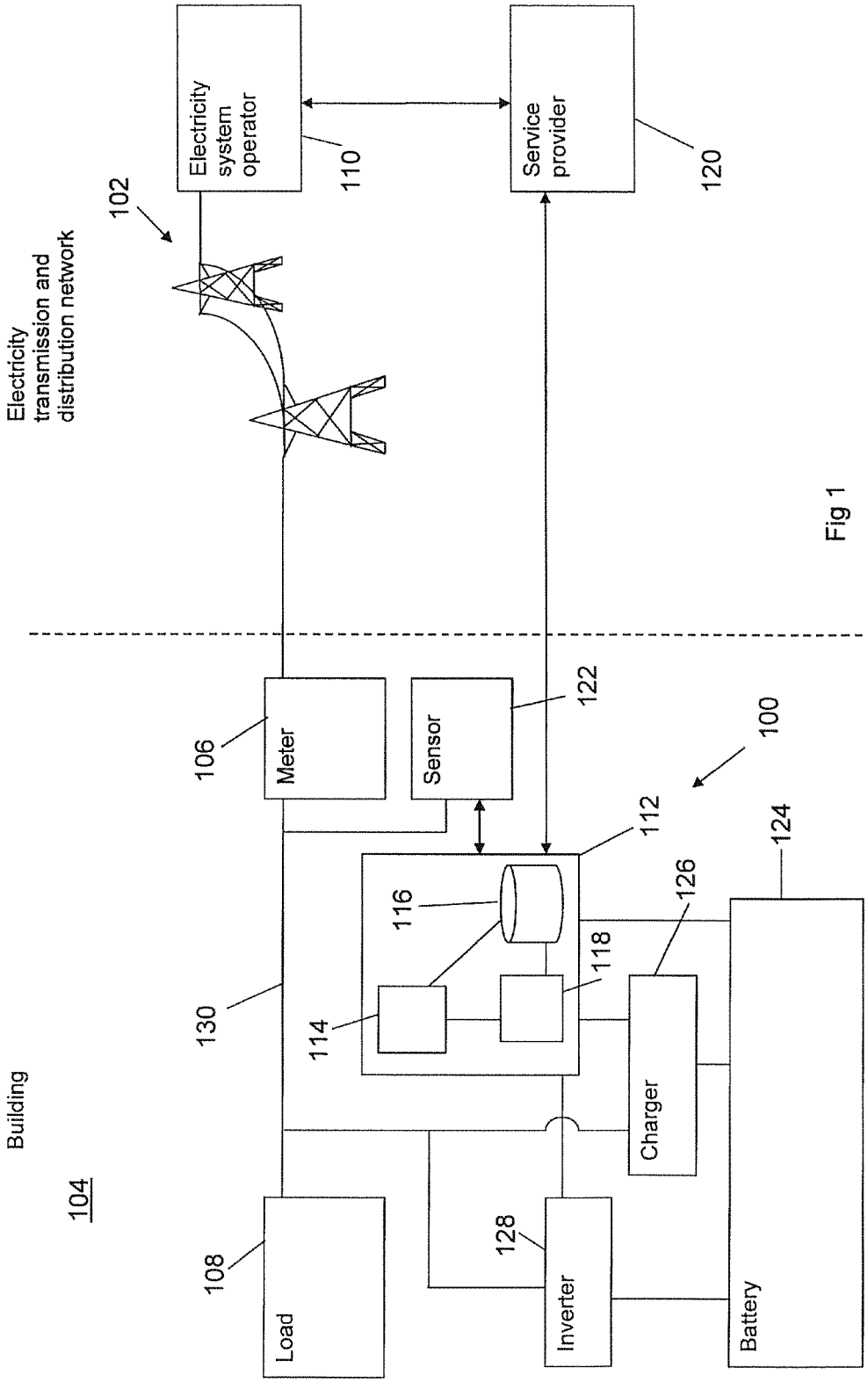
Electricity system operator
110
Service provider
120
102
Electricity transmission and distribution network
Building
104
106
Meter
Sensor
122
100
112
124
116
126
118
130
114
Charger
Load
108
128
Inverter
Battery

Fig 1

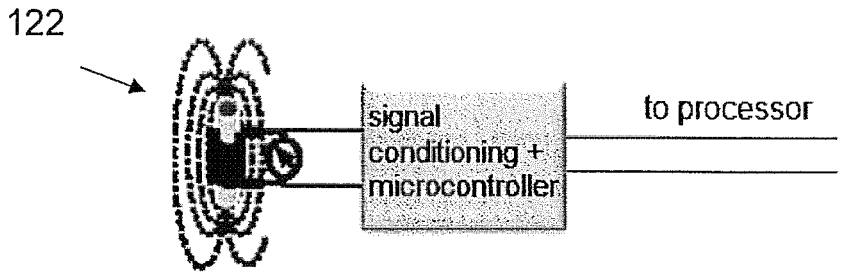
122
signal
conditioning +
microcontroller
to processor

Fig 3

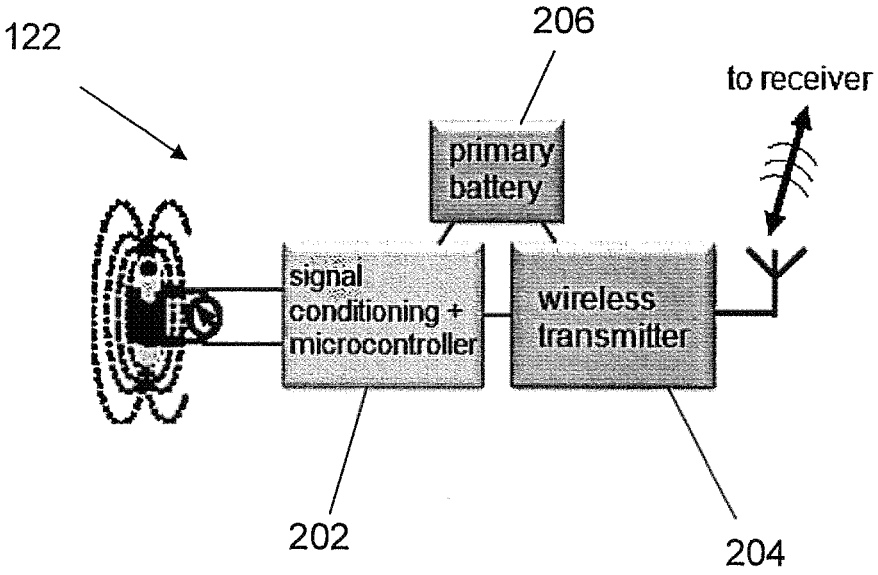
122
206
to receiver
primary
battery
signal
conditioning +
microcontroller
wireless
transmitter
202
204

Fig 2

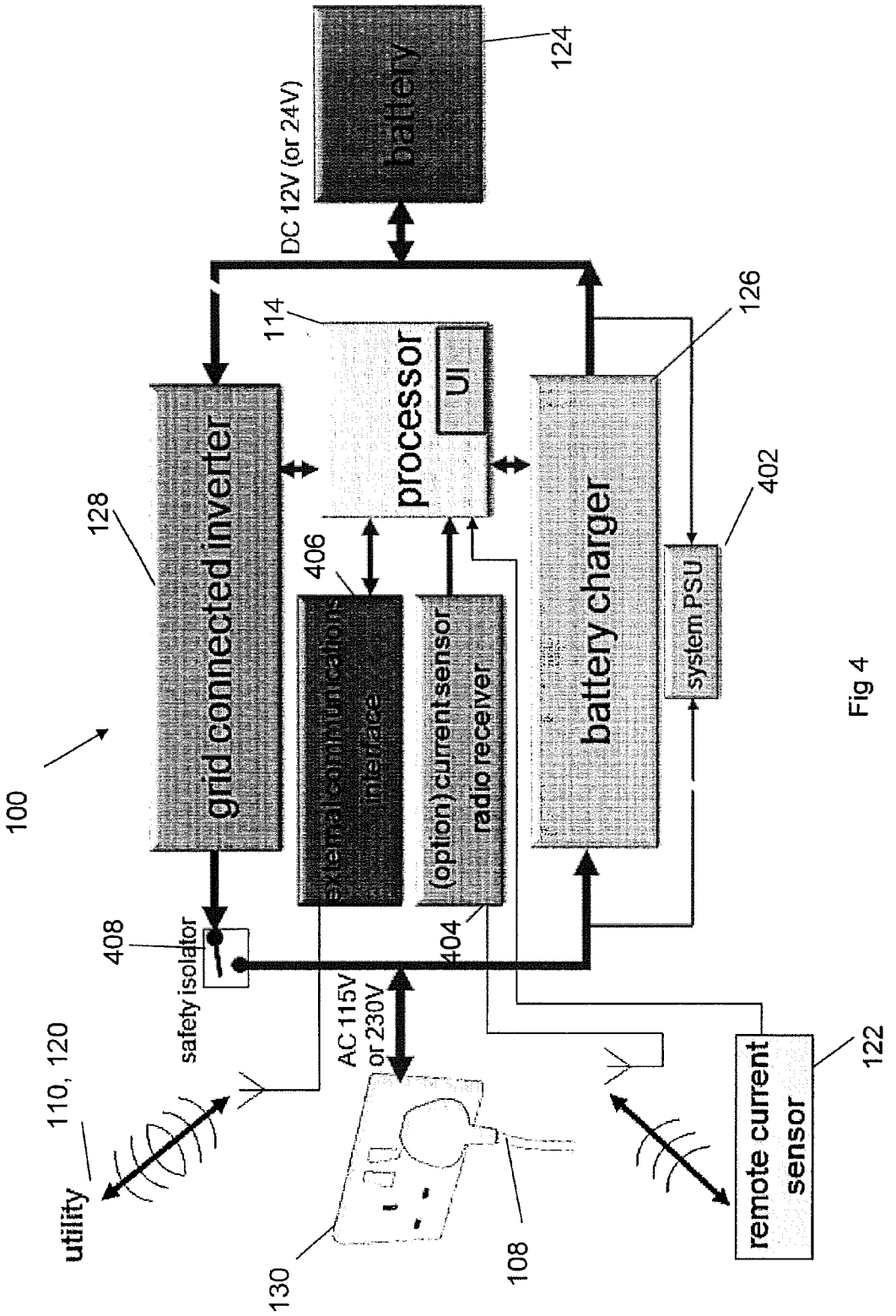
battery
124
DC 12V (or 24V)
114
processor
UI
126
grid connected inverter
128
406
external communications interface
(option) current sensor radio receiver
battery charger
system PSU
402
100
408
safety isolator
404
AC 115V or 230V
110, 120
utility
130
108
remote current sensor
122

Fig 4

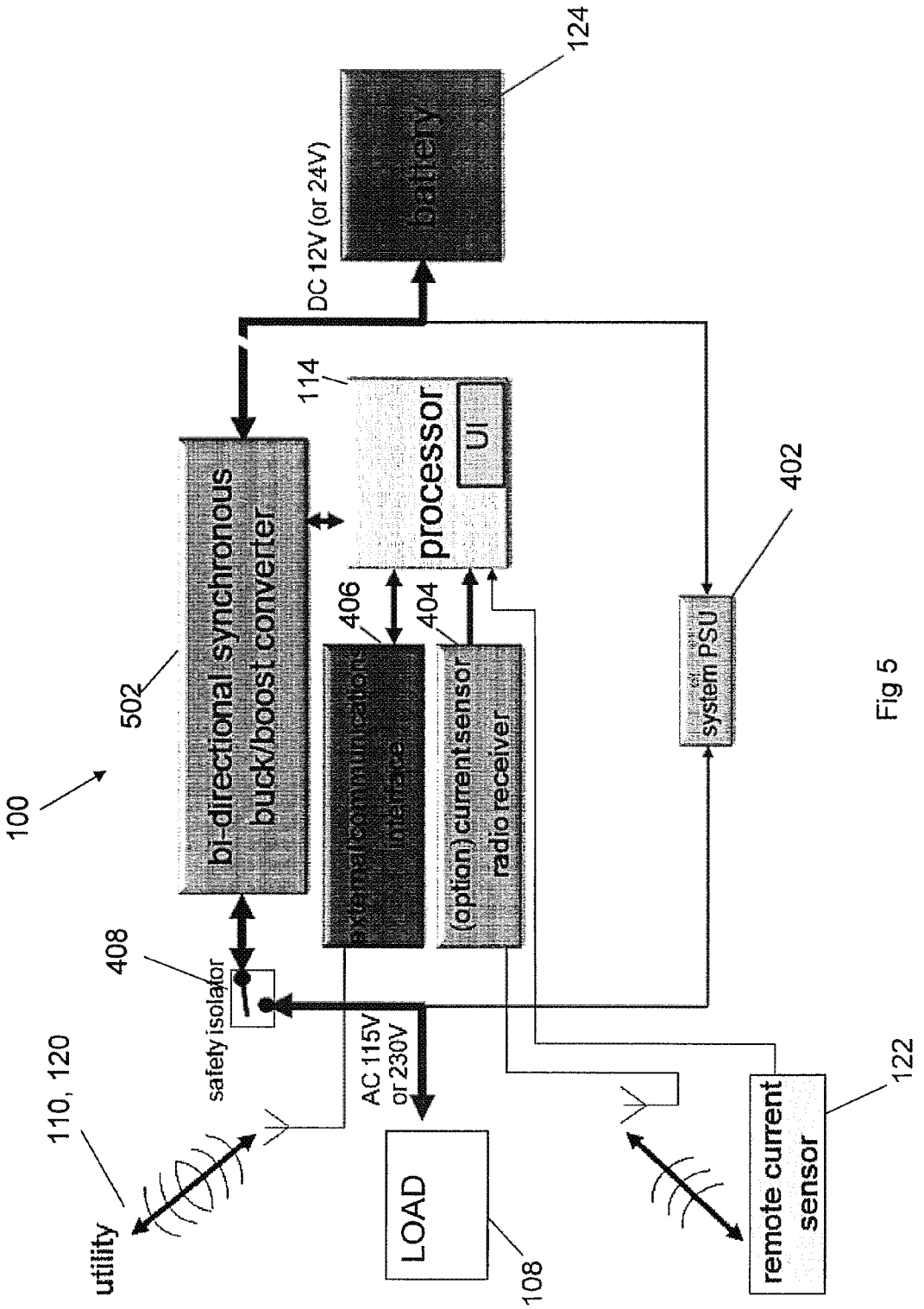
100
502
bi-directional synchronous buck/boost converter
DC 12V (or 24V)
battery
124
114
processor
UI
406
404
external communication interface
(option) current sensor radio receiver
402
system PSU
408
safety isolator
AC 115V or 230V
110, 120
utility
LOAD
108
remote current sensor
122

Fig 5

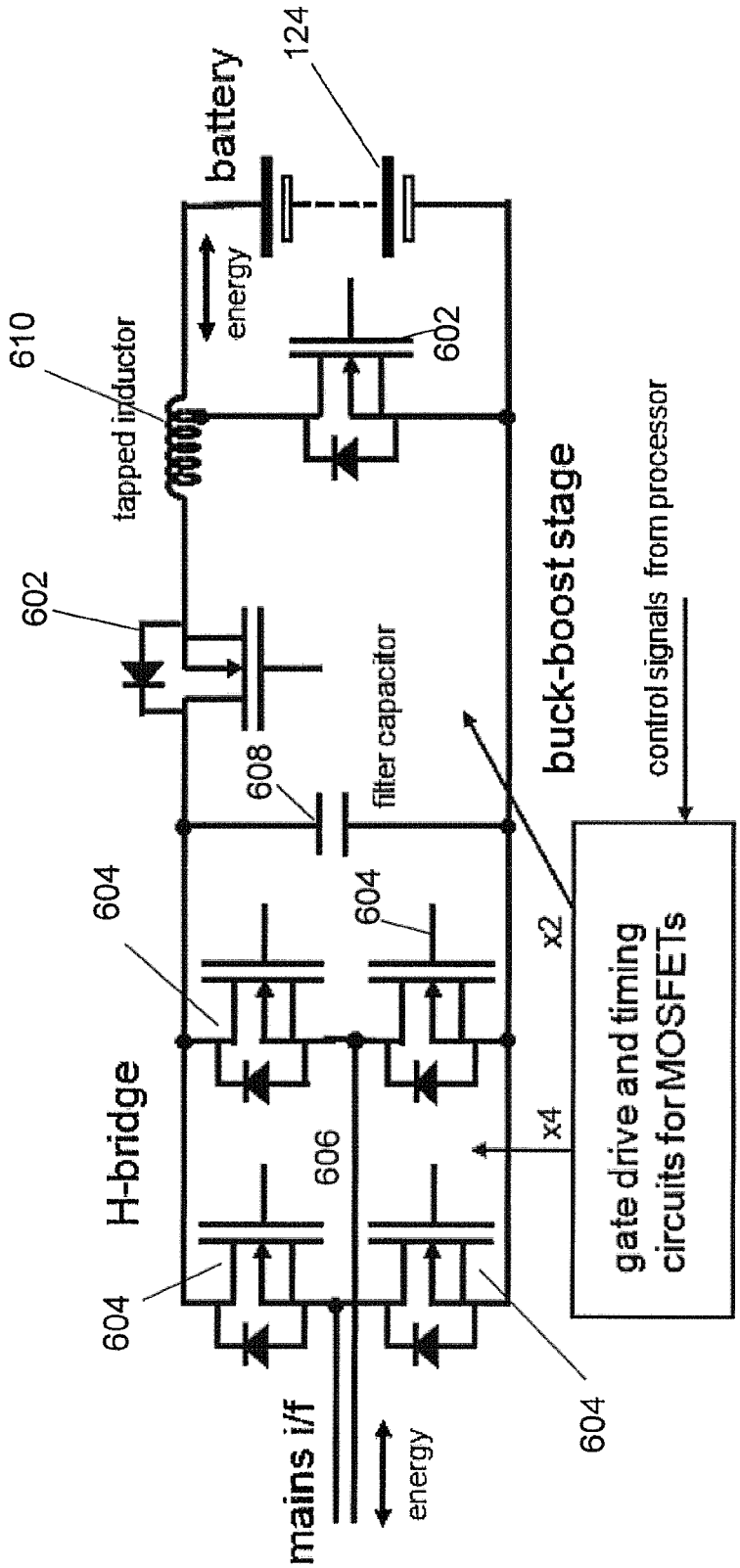
124
battery
energy
602
610
tapped inductor
602
filter capacitor
608
buck-boost stage
control signals from processor
604
604
x2
H-bridge
606
x4
gate drive and timing
circuits for MOSFETs
604
604
mains i/f
energy

Fig 6

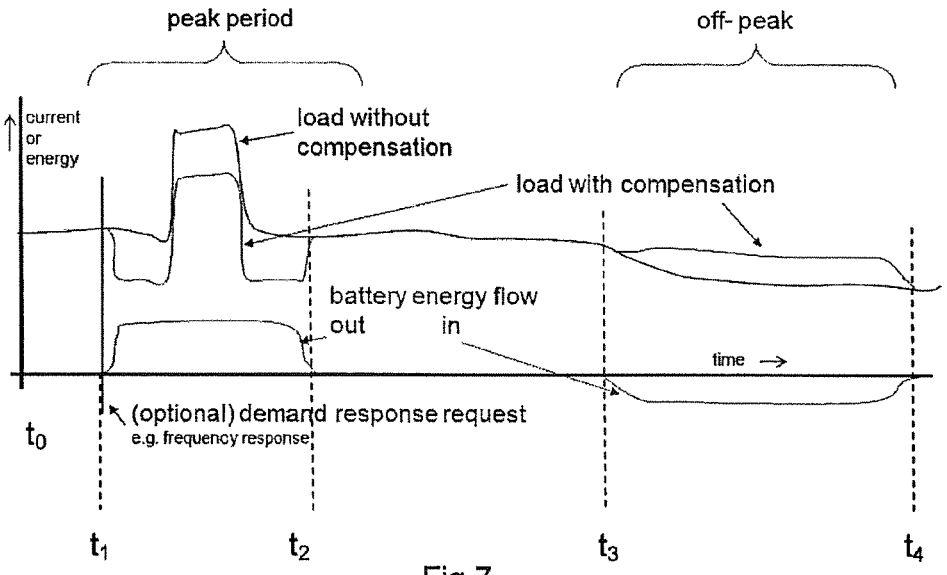
peak period
off- peak
current or energy
load without compensation
load with compensation
battery energy flow
out
in
time
(optional) demand response request
e.g. frequency response
t_0
t_1
t_2
t_3
t_4

Fig 7

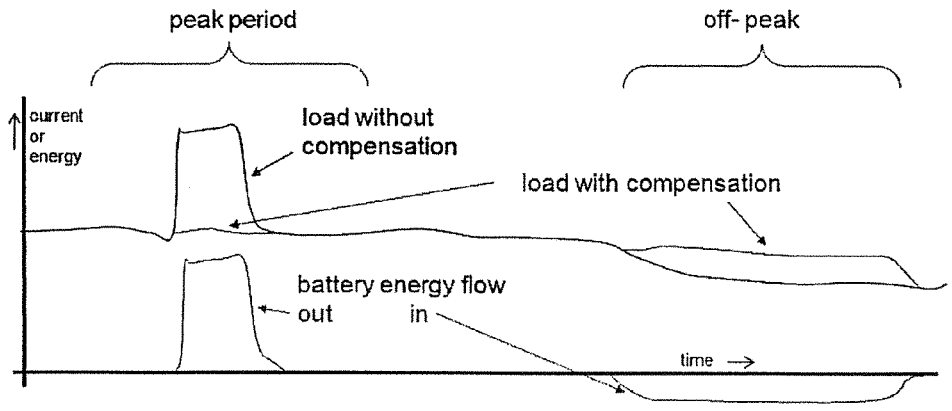
peak period
off- peak
current or energy
load without compensation
load with compensation
battery energy flow
out
in
time

Fig 8

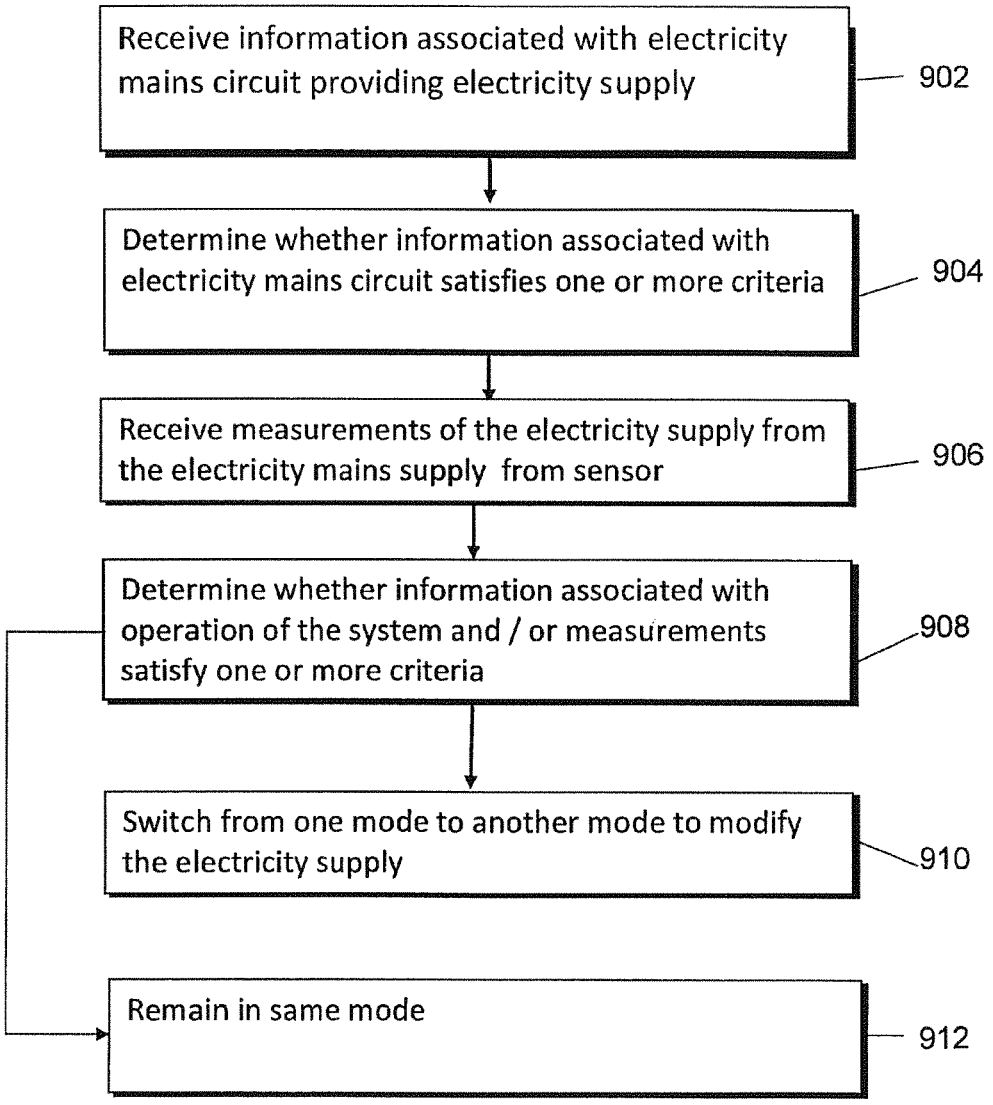
Receive information associated with electricity mains circuit providing electricity supply
902
Determine whether information associated with electricity mains circuit satisfies one or more criteria
904
Receive measurements of the electricity supply from the electricity mains supply from sensor
906
Determine whether information associated with operation of the system and / or measurements satisfy one or more criteria
908
Switch from one mode to another mode to modify the electricity supply
910
Remain in same mode
912

Fig 9

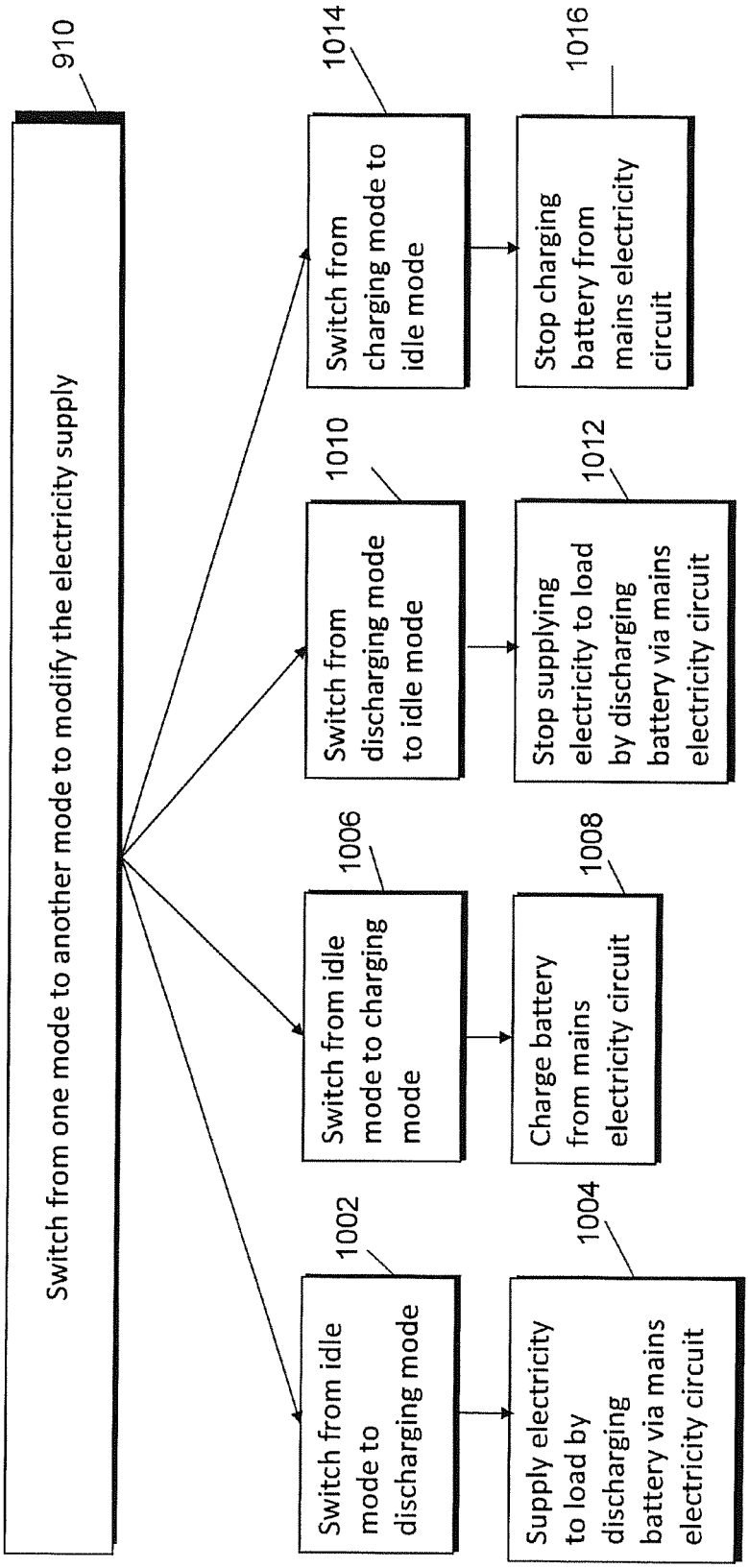
910
Switch from one mode to another mode to modify the electricity supply
1002
Switch from idle mode to discharging mode
1004
Supply electricity to load by discharging battery via mains electricity circuit
1006
Switch from idle mode to charging mode
1008
Charge battery from mains electricity circuit
1010
Switch from discharging mode to idle mode
1012
Stop supplying electricity to load by discharging battery via mains electricity circuit
1014
Switch from charging mode to idle mode
1016
Stop charging battery from mains electricity circuit

Fig 10

SYSTEM AND METHOD FOR CONTROLLING AN ELECTRICITY SUPPLY

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

More than one reissue application has been filed for reissue of U.S. Pat. No. 9,450,406. In addition to the present application, U.S. patent application Ser. No. 16/109,099, which is a reissue continuation of the present application, was filed Aug. 22, 2018. The present application *is an application for reissue of U.S. Pat. No. 9,450,406 issued Sep. 20, 2016, on U.S. Non-Provisional Patent Application No. 13/885,013 filed Jul. 24, 2013, and which* claims priority under 35 U.S.C. § 365 to International Patent Application No. PCT/EP2011/069978 filed Nov. 11, 2011, entitled "SYSTEM AND METHOD FOR CONTROLLING AN ELECTRICITY SUPPLY". International Patent Application No. PCT/EP2011/069978 claims priority under 35 U.S.C. § 365 and/or 35 U.S.C. § 119(a) to United Kingdom Patent Application No. 1019061.9 filed Nov. 11, 2010[which]. *These disclosures* are incorporated herein by reference into the present disclosure as if fully set forth herein.

TECHNICAL FIELD

The present invention relates to a method, apparatus and system for controlling an electricity supply.

BACKGROUND

There have been concerns over carbon-induced climate change and the increasing demand for electrical energy. The increase in demand for electrical energy can be attributed to each person using more electrical appliances and more transport and heating being powered by electricity.

In recent times there has been a trend to increase the capacity of cleaner electricity generation and to persuade consumers to modify their electricity usage. One way consumers can modify their electricity usage is to reduce their overall electricity consumption. However other benefits can be derived from consumers modifying how they consume electricity.

For example, consumers' electricity usage can be modified using a known set of techniques called Demand-Side Management (DSM) which comprises measures such as improving building insulation and building automation.

Demand Response (DR) is another known technique for modifying consumer's electricity usage. DR comprises reducing or time shifting electrical loads carried out either manually by a user or automatically.

Time shifting electrical loads can be useful for modifying the time of day when a consumer places a load on the electrical transmission and distribution network and in turn the electrical generation connected thereto. In particular, the overall electricity demand on a transmission and distribution network varies over the course of a day. For example, in certain countries peaks in electricity demand often occur in the evening and early in the morning when people are using electrical appliances at home. Supplying this varying load can be challenging for the electricity transmission and distribution network operators and electricity generators. The electricity transmission and distribution networks have to be scaled for the peak demand and generators would prefer to supply a constant base load without substantial variations.

Previously some financial incentives have been used to implement DR. Some electricity suppliers have provided a lower cost night-time electricity tariff for domestic consumers. Some industrial electricity consumers have agreements with the electricity supplier or network operator to reduce loads at peak times.

Once recent concept is a demand response aggregator which recruits electricity consumers who are willing to reduce or to time shift their electricity consumption. In this way the DR aggregator can offer the system supply operator the option of time shifting or reducing a larger aggregated load from the networks. This concept is also known as "negawatt" generation. In this way a DR aggregator can offer the system operator the option of negative electricity generation during times of peak load in the same way an electricity generator can offer conventional electricity generation.

In some countries, such as the UK, the system operator can pay for balancing services to help match supply and demand, particularly at peak times. Balancing services can vary by one or more factors and depending on the type of the balancing service, the amount paid by the system operator can vary. The factors affecting balancing services comprises one or more of the following: response time from a request to curtail a load or time shift a load; availability of curtailment capacity or load time shift capacity; time availability of the curtailment capacity or load time shift capacity; time period for which the load can be curtailed or time shifted; and the number of times per year the load can be curtailed and/or time shifted. This means a DR aggregator can be paid for balancing services and share these earnings with its recruited consumers. In particular the most valuable balancing service is a fast response load adjustment for electrical system frequency control, as the mains system frequency deviates from the ideal when there is an imbalance of supply and demand on the system.

Known solutions for implementing DR comprise manually or automatically switching off a load at the request of the system operator, via a supplier or aggregator. In the industrial and commercial sectors loads can be switched off automatically based on information relating to the electricity transmission network or perhaps manually based on information received over the telephone.

Domestic applications of DR are not yet widespread, partly because there is a need for a behaviour change by the consumers. For example, consumers in the residential sector are required to turn off e.g. air conditioning units or swimming pool pumps during peak times. However depending on the type of appliance the consumer is using, the consumer may not be willing to turn off their appliance or postpone using their appliance, for example a heater or a cooker, during peak periods. Furthermore, in some countries like the UK, there are a limited number of appliances which a consumer may be willing or able to turn off during a peak period. Moreover the cost of DR automation equipment can be substantial.

Another known way to implement DR in the domestic environment is to use smart plugs which comprise a processor which determines when to turn off an appliance based on various information. However, some appliances are not suitable for use with a smart plug which interrupts the electricity supply and the appliance, for example a washing

machine, may not return to the same state after an interrupted electricity supply resumes.

An uninterruptible power supply (UPS) is a known way to supply electricity to a load, for example servers and the like. A UPS receives electricity from a mains electricity supply and in turn supplies mains energy to devices plugged into it whilst charging an internal battery at the same time. The UPS keeps the battery charged so that if the input supply is lost, the battery can be used to generate an equivalent mains output to the load for a limited time period. This means the load does not experience an interruption in its electricity supply. However, the current UPS systems are expensive and require that the UPS is rated higher than the load attached.

SUMMARY

Some embodiments may address at least one of the disadvantages or problems discussed above.

In accordance with an embodiment there is provided a system for controlling an electricity supply to a load comprising at least one battery for storing energy; and a controller for determining when to switch between a first mode wherein electricity is supplied to the load from a mains electricity circuit; and
a discharging mode wherein electricity is supplied from the battery to the load via the mains electricity circuit; wherein the determining is based on information associated with the electricity supply.

Preferably the controller also determines when to switch to a charging mode wherein the battery is charged from the mains electricity circuit. The first mode can be the charging mode. Preferably the first mode is an idle mode wherein substantially no energy is transferred between the battery and the mains electricity circuit.

Preferably the system comprises a communication interface for receiving the information from a electricity network system operator or a service provider. Preferably the controller initiates connections with the electricity network system operator or a service provider via the communication interface. The information can comprise a request to switch between the idle mode, the discharging mode, and the charging mode.

Preferably the information associated with the electricity supply comprises one or more parameters of an electricity transmission and distribution network. The controller can determine when to switch when a value of the one or more parameters of the electricity transmission and distribution network is determined to be a predetermined range. The parameters of the electricity transmission and distribution network may be one or more of the following: time of the peak periods of load on the electricity network; time of the off-peak periods of load on the electricity network; price of electricity, available capacity of the electricity transmission and distribution network; time of imbalance between supply and demand on the electricity transmission and distribution network.

Preferably the system comprises a charger for charging the battery from mains electricity circuit when the system is in the charging mode. Preferably the system comprises an inverter for supplying the load with an electricity supply from the battery when the system is in the discharging mode. The controller may be configured to control the waveform of the electricity supply current from the inverter to the load. Preferably the charger and inverter comprise the same circuit. Preferably the system comprises a safety isolation switch for disconnecting the inverter output.

Preferably the system comprises a sensor for measuring one or more parameters of the electricity supply from the electricity transmission and distribution network to the load and for sending information regarding the measurements to the controller.

Preferably the controller determines to switch between the idle mode and the discharging mode or the charging mode further based on the received measurements.

Preferably the controller determines to switch from the idle mode or charging mode to the discharging mode when the current of the electricity supply to the load is above a pre-determined threshold. Preferably the sensor sends information to the controller about transitions of the current of the electricity supply to the load through one or more predetermined thresholds.

Preferably the controller determines to prevent switching to the discharging mode when information has not been received from the sensor for more than a maximum time period.

Preferably the controller determines that switching between the idle mode and the discharging mode or the charging mode is not required for a time period and controls the communication interface and sensor to reduce communication frequency for the time period.

Preferably the controller determines when to switch when a value of one or more parameters of the battery is determined to in be a predetermined range.

Preferably the controller is configured to control the rate at which the battery is charged and or discharged.

Preferably the controller is configured to prevent discharging of the battery if the loss of the electricity supply from the electricity transmission and distribution network is detected.

Preferably during the charging mode the electricity is supplied to the load from the mains electricity circuit.

Preferably the battery supplies electricity to the mains electricity circuit in the discharging mode and receives electricity from the mains electricity circuit in the charging mode using a single bi-directional connection with the mains electricity circuit.

Preferably the controller stores information about switches between the idle mode, the discharging mode and the charging mode over a time period and sends the switching information to the electricity network system operator or a service provider.

Preferably the controller may determine to carry out a battery maintenance procedure. The controller can also initiate a connection through the communication interface with another system and determines to switch based on information received from the other system.

In accordance with yet another embodiment there is provided a method for controlling an electricity supply to a load comprising: determining when to switch between a first mode wherein the load is supplied from a mains electricity circuit, and a discharging mode wherein the electricity is supplied to the load from a battery via the mains electricity circuit; wherein the determining is based on information associated with the electricity supply.

A computer program comprising program code means adapted to perform the method may also be provided.

In accordance with yet another embodiment there is provided a control apparatus for controlling an electricity supply to a load comprising: means for determining when to switch between a first mode wherein the load is supplied from a mains electricity circuit, and a discharging mode wherein electricity is supplied to the load from a battery via

the mains electricity circuit; wherein the determining is based on information associated with the electricity supply.

Various other aspects and further embodiments are also described in the following detailed description and in the attached claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention and as to how the same may be carried into effect, reference will now be made by way of example to the accompanying drawings in which:

FIG. **1** illustrates a schematic diagram according to some embodiments;

FIGS. **2** and **3** illustrate schematic diagrams of different types of connections between a sensor and a controller according to some embodiments;

FIG. **4** illustrates a system for controlling supply of electricity according to some embodiments;

FIG. **5** illustrates a system for controlling supply of electricity according to some other embodiments;

FIG. **6** illustrates a circuit diagram of a converter according to some more detailed embodiments;

FIGS. **7** and **8** illustrate graphs of time versus current or energy according to some embodiments;

FIG. **9** illustrates a flow diagram of a method according to some embodiments; and

FIG. **10** illustrates a more detailed flow diagram of a method according to some embodiments.

DETAILED DESCRIPTION

The following describes apparatus, systems and methods for controlling the electricity supply to a load from an electricity transmission network. In particular some embodiments relate to a system for storing electrical energy and later releasing it to a load in a building, under external control, to deliver financial and operational benefits to electricity utilities and consumers.

In this regard reference is made to FIG. **1** which illustrates a schematic diagram according to some embodiments. An electricity transmission and distribution network or utility **102** supplies electricity to a premises or building **104** via a meter **106**. The electricity transmission and distribution network **102** provides an electricity supply via one or more transformers (not shown) to step down the voltage of the electricity for the purposes of domestic or office use. Typically the electricity comprises an alternating current (AC). In this way the electricity transmission and distribution network **102** provides an electricity supply also known as "mains" electricity to the building **104** via a mains electricity circuit **130**. In some embodiments the electricity supply is not limited to domestic use but can be used in other sectors such as transport or industry. Typically the electricity transmission and distribution network **102** can be controlled and managed by an electricity system operator **110**.

The meter **106** comprises measuring apparatus for measuring the amount of electricity consumed by the building **104**. The meter can, in some embodiments be a "smart meter" which can detect multidirectional flow of electricity; electricity being consumed or electricity being supplied by the building **104** to the electricity transmission and distribution network **102**. In other embodiments, the meter is a traditional meter which only detects electricity consumed from the electricity transmission and distribution network **102**.

The building **104** consumes the electricity supplied by the electricity transmission and distribution network **102**. The consumption of electricity by the building **104** is represented by a load **108**. The load **108** can comprise the electrical demand of one or more electrical appliances which use electricity during their operation. For example, the load **108** of a domestic building can comprise electricity being consumed by heating, air conditioning, swimming pool pumps, washing machines, televisions, cookers, lighting, and any other suitable electrical means for using electricity.

The system **100** for controlling the electricity supply in the building **104** will now be described in further detail. The system **100** comprises a battery **124**, a charger **126** for charging the battery and an inverter **128** for providing a suitable electricity supply to the load **108** from the battery **124**.

The battery **124** can be any type of suitable means for storing electrical energy. In some embodiments the battery **124** comprises one or more lead-acid batteries, similar to batteries used in vehicles. A lead acid battery is a flooded liquid electrolyte type. Advantageously a lead acid battery is a simple and cheap option to use in the system **100**. Alternatively the battery **124** can comprise one or more sealed valve regulated lead acid battery (VRLA). A VRLA comprises an absorbent glass mat or gel electrolyte which does not require battery maintenance. In some other embodiments the battery **124** can comprise one or more lithium ion or any other suitable battery technology.

The charger **126** can be any suitable means for charging the battery **124** from the mains electricity circuit **130**. In some embodiments the battery can be charged from the mains electricity circuit in the building and the charger can be connected between meter and load. In some embodiments the charger **126** charges the battery **124** at a constant, low rate. Optionally the charger **126** can have a variable charge rate.

The inverter **128** can be any suitable means for converting the electrical energy stored in the battery **124** into an electrical supply suitable for the load **108**. Typically the battery **124** outputs a direct current (DC) voltage. The inverter **128** can take the DC voltage and convert the DC voltage into an AC voltage suitable for the appliances comprised in the load **108**. Preferably the inverter **128** can synthesise a full wave AC voltage which is compliant with the electricity supply of the electricity transmission network. Preferably the inverter converts a 12V DC output from the battery **124** into 115V 60 Hz or 230V 50 Hz output. In some embodiments the inverter **128** and the charger **126** are connected to the mains electricity circuit **130** by the same connection. In some embodiments the same connection is a bi-directional connection. In other embodiments the inverter **128** and the charger **126** are connected to the mains electricity circuit **130** with different connections.

The battery **124**, the charger **126** and the inverter **128** are controlled by the controlling apparatus **112** in some embodiments. The controlling apparatus **112** comprises one or more processors **114** coupled to internal memory **116** and other components **118** for controlling the supping of electricity to the load **108**. The processor **114** can be linked to a user interface for receiving instructions from a user. In some embodiments the user interface comprises a 2 line LCD display and one or more input keys or may be any other suitable user interface. The controlling apparatus **112** can also comprise a power supply unit (PSU) **402** as shown in FIG. **4** which can power the controlling apparatus. The PSU **402** can be powered by the either the load **108** or the battery **124**.

The processor **114** in some embodiments can be configured to execute various program codes. For example, the implemented program code may comprise a code for controlling the electricity supply to the load **108**. The implemented program codes can in some embodiments be stored, for example, in the memory **116** and specifically in a program code section of the memory **116** for retrieval by the processor **114** whenever needed. The memory **116** in some embodiments can further provide a section for storing data, for example, data that has been processed in accordance with the application.

The controlling apparatus **112** can further comprise an interface **406** as shown in FIG. **4** for receiving and/or sending information from the electricity system operator **110** and/or a service provider **120**. The service provider **120** in various embodiments is a demand response aggregator, an electricity retailer or a distribution network operator. The service provider **120** can provide instructions and/or information to one or more controlling apparatuses **112** in separate buildings.

The interface **406** of the controlling apparatus **112** can be an over-the-air type interface for communicating with the system operator **110** or service provider **120**. In some embodiments the interface comprises a GPRS, 3G or other mobile telecommunication based interface for providing a data link over-the-air with the system operator **110** or the service provider **120**. In other embodiments the interface **406** for communicating with the system operator **110** or the service provider **120** comprises a wireless network interface such as a 802.11x or WiFi™ interface. In this way the controlling apparatus **112** can communicate via the building's **104** wireless router (not shown) which provides a connection to the system operator **110** and the service provider **120** via an Internet connection. The user interface can be used to select an appropriate wireless network and input the relevant security key by the user during set up of the system **100**.

Alternatively, the wireless interface **406** can be a home area network (HAN) which is connected to a suitable gateway means. In some embodiments the HAN can be a short range radio link conforming to the Zigbee™ standard. Indeed the controlling apparatus **112** may include any suitable radio interface for communicating with the system operator **110** and/or the service provider **120**.

In some other embodiments the interface **406** of the controlling apparatus **112** can be a wired type connection such as an Ethernet connection with the building's **104** router (not shown) which provides a connection to the system operator **110** and the service provider **120** via an Internet connection. Alternatively the interface **406** can be a powerline communications (PLC) type interface. In this way a PLC interface can use the building's **104** power lines to communicate with the system operator **110** and/or the service provider **120**. In some other embodiments, a standard public operating telephone system (POTS) line can be used to communicate between the controlling apparatus **112** and the system operator **110** and/or the service provider **120**. Indeed the controlling apparatus may comprise any suitable interface for wired communications. Furthermore the controlling apparatus can comprise a plurality of the aforementioned interfaces to provide redundancy in communications with the system operator **110** and/or the service provider **120**.

The processor **114** of the controlling apparatus **112** can be configured to communicate with the system operator **110** and/or the service provider **120** using a standardised communication protocol. In particular, the processor **114** can be configured to send messages comprising a DLMS/COSEM (device language message specification/companion specification for energy metering) format.

In some embodiments the communication interface **406** can be optional. For example, the information from the electricity transmission network, such as the times of off-peak and peak electricity tariffs can be pm-programmed into the memory **116** of the controlling apparatus **112**.

A sensor **122** is located near the meter **106** for detecting and measuring the electricity supplied to the building **104**. In some embodiments the sensor **122** is a current sensor for detecting the magnitude and direction of the electricity supply current. The sensor **122** can be attached to the live input electricity cable either the electricity transmission and distribution network side **102** of the meter **106** or the building **104** side of the meter. In other embodiments the sensor can be configured to measure one or more other parameters of the electricity supply such as voltage and power factor.

The sensor **122** according to some embodiments is shown in FIG. **2**, which shows a schematic representation of the wireless sensor **122**. The sensor **122** comprises a processor **202** and a wireless interface comprises a transmitter/receiver **204** for communicating with the controlling apparatus **112** and a power source **206** such as a battery. The controlling apparatus **112** comprises a reciprocal wireless transmitter/receiver **404** as shown in FIG. **4**. The wireless interface between the sensor **122** and the controlling apparatus **112** can comprise any suitable wireless communication format such as Zigbee™ or Bluetooth™ or another suitable two way wireless communication format. Alternatively the wireless interface can be a one way wireless interface whereby the sensor **122** only sends measurements to the controlling apparatus **112**. The sensor **122** can also comprise circuitry for performing digital signal processing such as signal conditioning on the current measurements. In some embodiments the processor of the wireless sensor can detect whether the battery **206** of the wireless sensor has a low voltage. The processor of the sensor **122** can then send an indication to the controlling apparatus **112** that the wireless sensor **122** needs a replacement battery.

The sensor according to some other embodiments is shown in FIG. **3**, which shows a schematic representation of the wired sensor **122**. The sensor **122** comprises a processor **202** and a wired interface with the controlling apparatus **112**. In this way the sensor **122** sends the measurements via a fixed wire to the controlling apparatus **112**. A wire connection between the controlling apparatus **112** and the sensor **122** means that the sensor can be powered by the controlling apparatus **112** and can operate continuously.

In some embodiments the sensor **122** according the embodiments described in FIG. **2** or **3** makes measurements of the electricity supply continuously. Alternatively the sensor **122** periodically makes measurements of the electricity supply. Indeed the sensor **122** can change the frequency with which measurements of the electricity supply are made. In some embodiments the controlling apparatus **112** can configure the sensor **122** and in particular configure how the sensor **122** operates. For example, the sensor **122** of FIG. **2** can perform measurements more frequently during peak demand periods of the electricity transmission and distribution network **102** than measurements made during the off-peak demand periods of the electricity transmission and distribution network **102**. This can reduce the amount of energy drawn from the battery **206**.

In some embodiments the sensor **122** can be used to detect the condition where a net flow of electricity out of the

building **104** is possible, so that the controlling apparatus **112** can prevent the net flow of electricity out of the building **104**. Optionally the sensor **122** may not been needed. For example, in some embodiments the meter **106** is a "smart meter". This means that the meter **106** is designed to allow electricity to flow either in or out of the building **104**.

FIG. **4** shows are more detailed embodiment of the system **100** for controlling the electricity supply in the building **104**. For the purposes of clarity the same numbering has been used as in the embodiments shown in FIG. **1**. The embodiments shown in FIG. **4** are the same as the embodiments shown in FIG. **1** except that the system **100** for controlling the electricity supply further comprises a safety isolator **408**.

The safety isolator **408** is configured to prevent electric shock when the system **100** or the electricity transmission and distribution network **102** requires maintenance, or when the system **100** is disconnected from the load **108**. For example, if an out of range voltage, such as an under-voltage, is detected when there is a load present or if over-current flowing out is detected, then the electricity supply from outside the building **104** may be lost. In order to protect utility personnel potentially working outside the building **104** on fault rectification, the safety isolator may automatically open the connection from the inverter **128** to the electricity supply. The processor **114** of the controlling apparatus **112** may be configured to also shut down the inverter **128** and charger **126** when the safety isolator **408** trips. Furthermore, the safety isolator **408** can also automatically open the connection from the inverter **128** to the electricity supply when no current, or lower than expected current, is flowing out when the inverter **128** is on, or if over-voltage is detected at the output of the inverter. In order to protect a user from a potential electric shock on the plug, the safety isolator **408** will automatically open the connection from the inverter output to the mains electricity supply. Again, the processor **114** of the controlling apparatus **112** may be configured to also shut down the inverter **128** and charger **126** when the safety isolator **408** trips. In some embodiments the safety isolator **408** is actuated by the processor **114** of the controlling apparatus **112** once the processor **114** determines an under voltage or no current flowing when the inverter **128** is on based on received sensor **122** measurements. In some embodiments there may be a separate sensor (not shown) for detecting the current and/or voltage for actuating the safety isolator **408**.

FIG. **5** shows a schematic representation of some alternative embodiments. FIG. **5** is the same as the embodiments described in reference to FIG. **4** except that the inverter **128** and charger **126** are replaced with a bi-directional synchronous buck boost converter **502**. FIG. **6** shows a more detailed circuit diagram of the converter **502** used in the embodiments as shown in FIG. **5**.

The converter **502** comprises 2 high frequency switching MOSFETs **602** for both charging and discharging. The converter **502** further comprises four lower frequency switching MOSFETs **604** in the H-Bridge **606**. The lower frequency switching MOSFETs **604** can have a frequency of 100 Hz.

The converter **502** comprises a filter capacitor **608** which is small to improve reliability and reduce manufacturing costs over large capacitors. In some embodiments the battery **124** can be subjected to a minimally filtered 100 Hz current waveform. The capacitor **608** can be used to filter out the high switching frequency of the buck boost converter. In some circumstances the battery life **124** can be reduced if the battery is subjected to large current fluctuations. In some cases the filter capacitor **608** is set to a high enough value to avoid subjecting the battery **124** to large current fluctuations.

The converter **502** further comprises a tapped inductor **610** which is used to manage the duty cycle of the MOSFET **602** switching. As the duty cycle varies greatly in order to synthesise 100 Hz semi-sinewaves, some embodiments comprise means for limiting the maximum duty cycle. The tapped inductor **610** can help reduce voltage stress and the maximum duty cycle of the converter **502**.

For battery **124** discharge the converter **502** operates in a boost mode, synthesising from the battery energy, under processor and gate drive circuit control, full wave rectified sinewaves at the filter capacitor **608** for conversion to 50 Hz sinewaves by the H bridge under processor and gate driver control. In the discharge mode the battery energy augments the normal supply to the load.

For battery charging the H bridge, operating under processor and gate driver control, rectifies mains to a 100 Hz full-wave rectified signal at the filter capacitor **608** and the converter **502** operating in buck mode under processor and gate driver control delivers the energy to charge the battery **124**. The charging rate is controllable and charging can be done at unity power factor. In some embodiments the converter **502** can operate in a current control mode when charging and/or discharging the battery **124**.

In some embodiments the inverter **128** or converter **502** can be used to generate out-of-phase and/or non-sinusoidal current output when discharging the battery. The inverter **128** or converter **502** synthesises the current waveform to be delivered to the load **108** from the DC battery output, and is capable of providing a current waveform that has a predetermined phase angle and/or shape with respect to the mains supply voltage seen at the load **108**. The system operator **110** or service provider **120** may request or instruct the controlling apparatus **112** to deliver a discharge current with a certain phase angle and/or waveform shape relative to the voltage and the processor **114** instructs the inverter **128** or converter **502** to generate such a current waveform. Alternatively the controlling apparatus **112** and/or sensor **122** may determine the phase relationship between voltage and current seen at the load **108** based upon measurements of voltage and current waveform cycle timing, and then in response instruct the inverter **128** or converter **502** to deliver a pre-determined phase relationship in the discharge output, in order to provide compensation for a non-ideal measured supply phase relationship at the load **108**.

Operation of the system **100** for controlling the electricity supply will now be described in further detail with reference to FIG. **9**. FIG. **9** discloses a flow diagram of the method according to some embodiments.

The system **100** can operate in an idle mode whereby the load **108** of the building **104** is being supplied with electricity from the mains electricity circuit **130**. The mains electricity circuit **130** is in turn being supplied from the electricity transmission and distribution network **102** via the meter **106**. That is, the load **108** is running off mains electricity circuit **130**. In the idle mode the battery **124** does not draw or feed any electrical energy to or from the battery from or to the mains electricity circuit **130**. In reference to FIG. **7**, the system being in the idle mode is represented by t_0. FIG. **7** illustrates a graph of time versus energy for some embodiments.

The processor **114** may receive information associated with the mains electricity circuit **130** and/or the associated electricity supply. In some embodiments the information associated with the electricity supply comprises information associated with the electricity transmission and distribution

network **102** providing the electricity supply to the mains electricity circuit **130** as shown in block **902**. In some embodiments, the processor **114** can receive information comprising an indication of either the condition of the electricity supply, for example frequency or demand level or an indication of the condition of the network.

In some countries the frequency of the electricity supply may be 50 or 60 Hz.

In the UK, the electricity system operators are required to keep the electricity supply at 50 Hz±0.5 Hz. If the frequency changes from 50 Hz, this may indicate a mismatch between supply and demand. The frequency may need to change from 50 Hz by a predetermined amount in order to trigger a change in mode. That amount may be 0.2 Hz or more. However this is by way of example and in some implementations the predetermined amount may be more or less than 0.2 Hz. It should be appreciated that different countries may have different electricity supply frequencies and/or different tolerated deviations. As such this may change the predetermined amount.

In some embodiments, a change in frequency may be determined in order to determine if a mode should be changed.

It should be appreciated that alternatively or additionally another characteristic or parameter of the frequency of the supply (other than frequency value or change in frequency) may be used to trigger a change in mode.

In some embodiments the processor **114** may receive via the communication interface **406** information associated with the capacity of the network. The information associated with the capacity of the network can comprise information regarding the timing of peak and off peak demand on the network and the associated price of electricity. The information can comprise information about the availability of excess electricity from wind, solar or another renewable source at off-peak time. Furthermore the information can comprise the timing and optionally pricing of providing balancing services such as providing fast response frequency balancing services. The information associated with the capacity of the network may be received infrequently such as monthly. Alternatively the information can be received frequently such as every half hour, or as a time-critical immediate request to take action within a pre-determined time period, e.g. a few seconds. The latter request would permit a "real-time" response.

The processor **114** can also receive direct demand response requests from the system operator **110** or the service provider **120** as shown at t_1 in FIG. **7**. The demand response request may also be received by the communication interface **406**. The demand response request may be time critical. In response to receiving the demand response request, the processor **114** may be required to start discharging the battery **124** within a pre-determined time period, e.g. a few seconds. The request may indicate the length of time for which the battery is to be charged/discharged, the rate at which the battery is to be charged/discharged and/or the level to which the battery is to be charged/discharged and/or any other information.

In order to respond quickly to a time-critical demand response or balancing services request, the processor **114** may receive the request via a broadband connection using TCP/IP. TCP/IP or another secure connection protocol is preferred in order to avoid hacking or other security threats. The processor **114** is configured to open connections with the system operator **110** or the service provider **120** and send a message to a server (not shown). The message can interrogate the server as to whether there is an impending time-critical demand response or balancing services event. In some embodiments the processor **114** can receive information indicating that a time-critical demand response or balancing services event is likely. The processor **114** can keep a connection open with the server for a period of time and wait to receive a time-critical demand response or balancing services request. The connection can be configured to time out after a period of time and the processor **114** can re-open a connection with the server. In some embodiments the connection will remain open for 5 minutes. In some embodiments the processor **114** may immediately open a new connection when a previous connection has been closed. When a time-critical demand response or balancing services event is likely, such as during a time of peak capacity, the processor **114** may more frequently open connections with the server than at times during of off-peak capacity.

In some embodiments the processor **114** may optionally receive some messages warning about an impending time-critical demand response or balancing services event. The processor **114** can acknowledge the warning message. Alternatively, the processor **114** can respond to the warning message and indicate that the system **100** is not ready or cannot discharge the battery **124**.

The processor **114** may preferably initiate the opening of a connection to the server (not shown) using the hypertext transfer protocol secure (HTTPS). Alternatively the hypertext transfer protocol (HTTP) can be used together with security features to assist with authentication of the controlling apparatus **112**. The controlling apparatus **112** may be provided with a unique identification code at the time of manufacture, which can be used for secure log-in to the server.

The processor **114** and server may exchange information in order to test the effectiveness of the connection between them and ensure the connection is capable of meeting the response time requirements. The processor **114** can open a connection to the server and the server can subsequently send a dummy instruction that is not to be acted upon by the processor **114** other than for the processor **114** to establish the speed and quality of the connection and report the result to the server.

The processor **114** on receiving the information from the server of the system operator **110** or service provider **120** will then determine if the information satisfies one or more criteria as shown in block **904**.

For example, the processor **114** will determine if the demand response request requires immediate action or a later timed response. Alternatively for example, the processor **114** may determine that the price of the electricity is above a threshold. That is the processor **114** would determine that discharging is preferable when the price of electricity is high.

It should be appreciated that discharging the battery is used to augment the supply of electricity in some embodiments and in others may even replace the electricity supply.

Furthermore the processor **114** can be configured to determine if other information satisfies one or more predetermined criteria. In some embodiments the processor **114** can determine whether the mains electricity is present, and thus whether it is safe to operate the system **100**, from information received from the sensor **122** or from other measurement circuits, the discharge being disabled if there is no mains electricity present. The processor **114** may also determine whether other suitable parameters of the electricity transmission and distribution network satisfy predetermined criteria. The processor **114** may receive information

about parameters of the electricity transmission and distribution network **102** or about the mains electricity circuit **130** from the sensor **122**.

Once the processor **114** has determined that the information of the electricity transmission and distribution network **102** satisfies the correct criteria, the processor determines whether information associated with the system **100** satisfy one or more criteria as shown in block **908** and described below.

The processor **114** can determine information associated with the system **100** from received measurements from the sensor **122** as shown in block **906**. The measurements are received from the sensor **122** periodically whilst the sensor is active. That is the measurements can be received before the processor **114** receives the demand response request.

Operation of the current sensor will now be discussed. The sensor **122** in some embodiments continually measures the current of the electricity supply into the building **104**. In some buildings **104** the meter **106** is not a smart meter and therefore the meter **106** cannot accommodate a net current flow from the building **104** to the electricity transmission and distribution network **102**. Therefore the sensor **122** detects fluctuations of the current of the electricity supply relative to certain thresholds.

The sensor **122** is configured in some embodiments to send a message to the controlling apparatus **112** when the current of the electricity supply into the building **104** makes a transition in either direction through a first current threshold corresponding to the maximum output current of the inverter **128**. When the processor **114** determines that the total current of the electricity supply is below that of the maximum output of the inverter **128**, the processor **114** does not initiate turning the inverter **128** on if a demand response is requested. Alternatively the processor **114** reduces the maximum current output of the inverter **128** such that output of inverter **128** does not cause a net current out of the building **104**. In this way the total net current into the building is kept above 0 amps.

The sensor **122** is also configured to send a message to the controlling apparatus **112** when the current of the electricity supply into the building **104** makes a transition in either direction through a threshold corresponding to a near zero net total current of the electricity supply into the building **104**. The processor **114** determines that if the total current into the building **104** is near zero, then the processor **114** initiates the inverter to reduce its output or turn off in order to keep the current of the electricity supply a net inflow. During a period of time where the current value remains above or below either threshold, the wireless current sensor only transmits a periodic signal to indicate to the processor **114** that the sensor **122** is still working and the communication link is good.

In some embodiments the sensor **122** is configured to send a message to the controlling apparatus **112** when the current flowing into the load **108** changes by a value more than a pre-determined amount.

In some embodiments the wireless sensor **122** is configured to operate in a low power mode during certain time periods. During the low power modes, the sensor **122** transmits less or no messages to the controlling apparatus **112**. In some embodiments the sensor **122** is configured to operate in a low power mode during the times when a demand response event is not likely to occur, for example in off-peak periods. The processor **114** can send the timings of the periods of time to the sensor **122** when the sensor **122** can operate in a low power mode. In this way the sensor **122** can conserve battery life.

In some embodiments a wired sensor **122** is used with the controlling apparatus **112**. In this case the sensor **122** can continuously transmit current measurements to the controlling apparatus **112** and the processor **114** of the controlling apparatus **112** can determine whether the current measurements go above or below pre-determined current thresholds.

The processor **114** determines that the sensor **122** is operational having received at least one or more messages from the wireless sensor within a pre-determined maximum time period. If the processor determines that the sensor **122** is not operational, the processor **114** may avoid discharging the battery **124** because the processor **114** cannot be sure that the net inflow current of the electricity supply will remain above zero. If the processor **114** determines that the sensor **122** has a low battery, the processor **114** can display a notification for a user.

The processor **114** determines whether the inflow current of the electricity supply into the building **104** is above the threshold of the maximum output of the inverter **128**. As mentioned above, in embodiments in which there is no smart meter present in the building, the processor **114** may prevent discharging the battery if the discharge of the battery **124** would cause a current outflow of the building **104**.

The processor **114** may determine the state of charge of the battery **124**. In some embodiments the processor determines whether the charge of the battery is above an upper threshold indicating that the battery has a substantially full charge. For example the processor may initiate the discharge of the battery **124** if the charge of the battery **124** is above 80%.

If the processor determines that the criteria have not been met, the processor **114** determines that the system should stay in the same mode, as shown in block **912**. For example, if the system is in the idle mode, the processor **114** determines that the system will remain in the idle mode. Similarly if the system **100** is in the discharging mode or the charging mode, the system will remain in the same mode.

If the processor determines that the criteria have been met, the processor **114** determines that the system should switch from one mode to another mode to modify the electricity supply as shown in block **910**.

Switching between modes will be discussed by referring to FIG. **10** which shows a schematic flow diagram of switching between different modes to modify the electricity supply. The processor determines that the system should switch from the idle mode to the discharging mode and initiates the switch as shown in block **1002**. In the idle mode, the system **100** is connected to the mains electricity circuit **130** but the system does not feed or draw current to or from the mains electricity circuit. FIG. **7** illustrates the system switching from the idle mode to the discharging mode at time t_1.

In the discharging mode, the processor **114** initiates discharge of the battery **124** and subsequently electricity is supplied to the load **108** from the battery **124** via the mains electricity circuit **130** as shown in block **1004**. In some embodiments the electricity is supplied to the load **108** from the battery **124** and from the mains electricity supply in the discharging mode.

FIG. **7** indicates discharge of the battery **124** showing the battery **124** energy flow out and the corresponding load of the building **104** being reduced by an equivalent amount.

In some embodiments, preferably when meter **106** is a smart meter, the system **100** may discharge the battery **124** into the load **108** and through the meter **106** into the transmission and distribution network **102**.

The processor **114** initiates stopping the discharge of the battery **124** if the system or the electricity transmission network meet certain conditions. In particular the processor is configured to stop the discharge of the battery if one or more of the follow conditions are met; a loss of mains electricity supply, a battery charge of less than a predetermined charge level, e.g. 40%, the inflow current of the mains electricity supply being below the threshold for the near zero net current flow, a wireless current sensor fault, a low price, a request to stop the discharge, a request to start charging, or the expiry of a pre-determined discharge period.

If the criteria are met, the processor **114** then initiates switching from the discharge mode back to the idle mode as shown in block **1010** of FIG. **10**. FIG. **7** shows the switch of the system from the discharging mode to the idle mode at time t_2. The battery **124** stops discharging and supplying the load via the mains electricity circuit **130** and the load **108** of the building **104** returns to a pre-discharge level as shown in block **1012**.

At time t_3 the processor **114** determines that the electricity transmission and distribution network **102** is an off-peak period. In some embodiments the processor **114** will initiate charging the battery **124** if the following conditions are met; the mains electricity supply is present, the battery has a charge of less than a pm-determined charge level, e.g. 90%, and the price of the electricity is low. Alternatively the processor **114** initiates a charging of the battery **124** if a direct charge request is received. The processor **114** determines that the system **100** needs to switch from the idle mode to the charging mode, which is shown in block **1006**. The battery **124** is then charged from the mains electricity circuit **130** as shown in block **1008**.

FIG. **7** shows that whilst the battery **124** is charging, energy is flowing into the battery **124** and the total load of the building **104** is increased. During the charging mode the mains electricity circuit can supply electricity to the load **108** and the battery **124** via the charger **126**. This means that the charging of the battery **124** can be considered to comprise part of the load of the building **104** since the total load of the building **104** increases.

The processor **114** determines that the charging stops on determining one or more of the following conditions; loss of the mains electricity supply, a state of charge of the battery **124** of mom than a pre-determined charge level, e.g. 95%, a high price, a direct request to stop charging, a direct request to discharge, or the expiry of a pre-determined charging period.

Time t_4 shows the point whereby the battery has stopped being charged and the load **108** returns to a pre-charge load. That is the processor **114** causes the system to switch from the charging mode to the idle mode as shown in block **1014**. In this way, the battery **124** stops being charged from the mains electricity circuit **130** as shown in block **1016**.

In some embodiments the processor **114** can also cause the system to switch from the discharging mode to the charging mode or vice versa in dependence of information associated with the mains electricity supply.

In some embodiments the processor **114** may initiate a battery maintenance cycle, in response to measurements of battery condition and taking account of information from the system operator **110** or service provider **120** concerning the condition of the electricity transmission and distribution network **102**. In some embodiments the processor **114** may initiate a discharge and charge cycle of the battery according to manufacturer's specifications. The processor **114** preferably discharges during peak periods and charges during off peak periods. The processor **114** may ensure that the maintenance is initiated during a period whereby a demand response event is not expected to occur.

In some embodiments the processor **114** may initiate periods of charging the battery **124** in order to ensure the battery is in a state of full charge. The battery **124** may require a top-up charge because the battery **124** may lose a small amount of charge over time. In additional embodiments other maintenance to the battery may be carried out such as maintaining the battery cell balance by charging the battery **124** at an over-voltage and requiring the user to top up the battery with distilled water.

FIG. **8** illustrates a graph of energy versus time according to some embodiments. Operation of the system is similar to the embodiments described with reference to FIG. **7**. In addition the processor **114** can be configured to reduce the load **108** of the building **104**. The processor **114** detects that a large load such as a washing machine has been switched on during peak usage. The processor receives a message from the wireless sensor **122** that the load has increased and information about the amount of the load current increase, and initiates discharging the battery **124** so as to match the discharge current to the load increase. In this way a peak reduction that emulates the time shift of the appliance is achieved without actually performing time-shifting use of the appliance.

In this way the embodiments do not require the consumer to change their behaviour to implement peak load reduction. Indeed the consumer is not even aware that the system is operating. Furthermore advantageously the system allows time shifting of consumption of electricity and therefore the to peaks in electricity usage can be mitigated without the consumer changing behaviour. This means that less electricity generation capacity needs to be built because the electricity usage peaks can be smoothed out and existing capacity is sufficient.

In certain embodiments the processor **114** can record in memory **116** a history of events or log including one or more of the following demand response events, charging events (e.g. timing, duration and amount of energy), discharging events (e.g. timing, duration and amount of energy), and maintenance cycles over a period of time such as a week, month or year. The processor **114** via the interface **406** can initiate a periodic upload of this history to the system operator **110** or service provider **120**. Alternatively the system operator **110** or service provider **120** can via the interface **406** interrogate the processor **114** to request an upload of the history. In some embodiments the processor **114** may periodically send a message to notify the status of the system **100** and the availability of the system **100** to the system operator **110** or the service provider **120**.

In some embodiments the controlling apparatus **112** can take measurements of the condition of the electricity supply from the transmission and distribution network **102** such as voltage and power factor (phase angle between voltage and current at the load **108**) and send the measurements via the interface **406** to the system operator **110** or service provider **120**.

In some embodiments the information which is used to switch a mode may need to be present for at least a predetermined length of time. By way of example only, the deviation from a frequency threshold may need to be present for at least a predetermined length of time in order to cause a mode to be switched.

In some embodiments, the system may be associated with a load **108** that is made up of two or more buildings or premises. There may be a meter positioned in the electricity transmission and distribution network. Alternatively there

may be no meter and no sensor. The load made up of the two or more buildings or premises may operate in a similar way to the previously described embodiments.

Various different parameters and/or information has been described as being used to control the switching from one mode to another. It should be appreciated, that in some embodiments, only one parameter/information is taken into account. In some embodiments more than one parameter/information may be used. In some embodiments, the information/parameter(s) used to control the switching from one mode to a second may be different from that used when switching from the second or another mode.

In general, the various embodiments of the invention may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

The embodiments of this invention may be implemented by computer software executable by a data processor, such as in the processor entity, or by hardware, or by a combination of software and hardware. Further in this regard it should be noted that any blocks of the logic flow as in the Figures may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions.

The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multi-core processor architecture, as non-limiting examples.

Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the exemplary embodiment of this invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention as defined in the appended claims. Indeed there is a further embodiment which comprises the combination of two or more embodiments herein described.

The invention claimed is:

1. An apparatus for controlling an electricity supply to a load comprising:

a controller configured to determine based on *first* information associated with the electricity supply when to switch between a first mode wherein electricity is supplied to the load from a mains electricity circuit and a discharging mode wherein electricity is supplied from **[**a**]** *at least one* battery to the load via the mains electricity circuit,

wherein the controller is configured to determine when to switch to a charging mode, wherein the *at least one* battery is charged from the mains electricity circuit,

wherein the controller is configured to have a connection with an electricity network system operator or a service provider via a communication interface, the communication interface configured to receive the *first* information from the electricity network system operator or the service provider, **[**and**]**

wherein the controller is configured to **[**provide second information**]** *store historic switching information about switches between the first mode, the discharging mode and the charging mode over a time period and to periodically send the stored historic switching information* to the electricity network system operator or the service provider via the communication interface,

wherein the controller is configured to determine that switching between the first mode and the discharging mode or the charging mode is not required for a second time period and to control the communication interface to reduce communication frequency for the second time period, and

wherein the first information comprises frequency information, the frequency information comprising a deviation of a frequency of the electricity supply from a given value.

[2. The apparatus as claimed in claim **1**, wherein said received information comprises frequency information, wherein said frequency information comprises a frequency of said electricity supply, and wherein said frequency information comprises a deviation of a frequency of said supply from a given value.**]**

3. The apparatus as claimed in claim **1**, wherein **[**said received**]** *the first* information comprises an imbalance between a supply and a demand for the electricity supply.

4. The apparatus as claimed in claim **3**, wherein **[**said**]** *the* imbalance is indicated by **[**a**]** *the* deviation of **[**a**]** *the* frequency of **[**said**]** *the electricity* supply from **[**a**]** *the* given value.

5. The apparatus according to claim **1**, wherein **[**said received**]** *the first* information *further* comprises one or more parameters of an electricity transmission and distribution network or **[**said**]** *the* electricity supply, wherein the one or more parameters comprise one or more of the following:

time of peak periods of load on the electricity *transmission and distribution* network;

time of off-peak periods of load on the electricity *transmission and distribution* network;

price of electricity;

available capacity of the electricity transmission and distribution network; and

time of imbalance between supply and demand on the electricity transmission and distribution network.

6. The apparatus according to claim **1**, further comprising at least one sensor configured to measure at least one of frequency information, imbalance information and one or more parameters of the electricity supply and to provide information regarding the measurements to the controller.

[7. The apparatus according to claim 1, wherein the controller is configured to determine that switching between the idle mode and the discharging mode or the charging mode is not required for a time period and to control the communication interface to reduce communication frequency for the time period.]

[8. The apparatus according to claim 1, wherein the controller is configured to store information about switches between the idle mode, the discharging mode and the charging mode over a time period and to send the switching information to an electricity network system operator or a service provider.]

9. The apparatus as claimed in claim 1, wherein the *first* information *further* comprises a request to switch between the [idle] *first* mode, the discharging mode, and the charging mode, and wherein [said received] *the first* information *further* comprises a real time command.

10. A system comprising the apparatus as claimed in claim 1, *the system further comprising:*

the at least one battery configured to store energy,

a charger configured to charge the *at least one* battery from [a] *the* mains electricity circuit when in the charging mode, and

an inverter configured to supply the load with an electricity supply from the *at least one* battery when in the discharging mode,

wherein the *at least one* battery is configured to supply electricity to the mains electricity circuit in the discharging mode and receive electricity from the mains electricity circuit in the charging mode using a single bi-directional connection with the mains electricity circuit.

11. The system according to claim 10 wherein the controller is configured to control a waveform of [the] *an* electricity supply current from the inverter to the load.

12. A method for controlling an electricity supply to a load comprising:

determining when to switch between a first mode wherein the load is supplied from a mains electricity circuit, and a discharging mode wherein [the] electricity is supplied to the load from a battery via the mains electricity circuit;

storing historic switching information about switches between the first mode, the discharging mode and a charging mode over a time period;

periodically communicating the stored historic switching information to a system operator or a service provider associated with an electricity transmission and distribution network; and

determining that switching between the first mode and the discharging mode or the charging mode is not required for a second time period and reducing communication frequency for the second time period;

wherein the determining is based on *second* information associated with the electricity supply,

wherein the second information comprises frequency information, the frequency information comprising a deviation of a frequency of the electricity supply from a given value, and

wherein [said] *the second* information *further* comprises one or more parameters of [an] *the* electricity transmission and distribution network or [said] *the* electricity supply,

wherein the one or more parameters comprise one or more of the following:

time of peak periods of load on the electricity *transmission and distribution* network;

time of off-peak periods of load on the electricity *transmission and distribution* network;

price of electricity;

available capacity of the electricity transmission and distribution network; and

time of imbalance between supply and demand on the electricity transmission and distribution network.

[13. A computer program comprising program code adapted to perform the steps of claim 12 when the program code is run on at least one processor.]

14. The method as set forth in claim 12, further comprising:

[determining information comprising] sensing at least one of frequency information, imbalance information, and *the* one or more parameters of the electricity supply.

15. The method as set forth in claim 12, further comprising:

detecting a loss of the electricity supply from the electricity transmission and distribution network; and

preventing discharging of the battery when [said] *the* loss is detected.

[16. The method as set forth in claim 12, further comprising storing information about switches between the idle mode, the discharging mode, and a charging mode over a time period and communicating the switching information to an electricity network system operator or a service provider.]

17. The method of claim 12, wherein [said] *the* imbalance is indicated by [a] *the* deviation of [a] *the* frequency of [said] *the* supply from [a] *the* given value.

18. An apparatus for controlling an electricity supply to a load comprising:

a controller configured to:

determine based on *first* information associated with the electricity supply when to switch between a first mode wherein electricity is supplied to the load from a mains electricity circuit and a discharging mode wherein electricity is supplied from [a] *at least one* battery to the load via the mains electricity circuit, [and]

determine when to switch to a charging mode, wherein the *at least one* battery is charged from the mains electricity circuit, *and*

store historic switching information about switches between the first mode, the discharging mode, and the charging mode over a time period and to periodically send the stored historic switching information to an electricity network system operator or a service provider; and

a communication interface configured to receive the *first* information from an external source, wherein the *first* information comprises a request to switch between an idle mode, the discharging mode, and the charging mode, and wherein [said received] *the first* information *further* comprises a real time command,

wherein the controller is further configured to determine that switching between the first mode and the discharging mode or the charging mode is not required for a second time period and to control the communication interface to reduce communication frequency for the second time period,

wherein the first information further comprises frequency information, the frequency information comprising a deviation of a frequency of the electricity supply from a given value.

[19. The apparatus as set forth in claim 18, wherein the controller is configured to store information about switches between the idle mode, the discharging mode, and the

charging mode over a time period and to send the switching information to an electricity network system operator or a service provider.]

20. A system comprising [an] *the* apparatus as claimed in claim **18**, *the* at least one battery configured to store energy, a charger configured to charge the *at least one* battery from [a] *the* mains electricity circuit when in the charging mode, and an inverter configured to supply the load with an electricity supply from the *at least one* battery when in the discharging mode,

wherein the *at least one* battery is configured to supply electricity to [a] *the* mains electricity circuit in the discharging mode and receive electricity from the mains electricity circuit in the charging mode using a single bi-directional connection with the mains electricity circuit.

21. The system according to claim **20**, wherein the controller is configured to control a waveform of [the] *an* electricity supply current from the inverter to the load.

22. The apparatus according to claim **18**, wherein the controller is configured to prevent discharging of the battery if a loss of the electricity supply from an electricity transmission and distribution network is detected.

23. The apparatus according to claim **18**, wherein:

the communication interface is configured to receive the *first* information from an electricity network system operator or a service provider; and

the controller is configured to have a connection with the electricity network system operator or the service provider via the communication interface, and wherein the controller is configured to provide [second] *the historic switching* information to the electricity network system operator or the service provider via the communication interface.

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