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(54) Title: SCALABLE AUTONOMOUS ENERGY COST AND CARBON FOOTPRINT MANAGEMENT SYSTEM

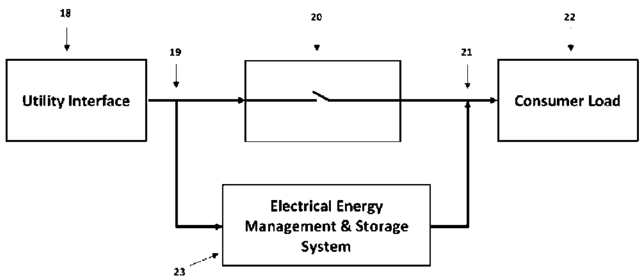

Figure 1

(57) Abstract: This invention relates to the use of technology to create a Smart Grid of distributed equipment operating as stand alone, or in a cluster without limitation to size or number, in unison or individually to manage energy cost and carbon footprint of its users. A scalable autonomously controlled apparatus together with the associated computer-implemented platform, comprising database server and associated enabling technology required to facilitate communications with the apparatus, to provide energy cost and carbon footprint management system. Scalable innovation of this invention enables plurality of apparatus to perform simultaneously on single or multiple circuits, to support energy requirement of larger loads. Autonomous innovation of the apparatus enables intelligent decision making required to optimise the consumer's energy cost and carbon footprint, as constrained by the consumer. The invention is able to seperate the event of purchasing energy, from that of its use, and in so doing the invention will depending on the user's setting, not only enable purchase at least cost and/or least CO_2/kWh emissions, but also moderate the energy demand curve. Degree of autonomy is unlimited and includes without limitation multi-objective optimisation, based on self-learning linear and non-linear forecasting. Extent of autonomy enables the apparatus to monitor component parameters within, such that the apparatus is able to determine deteriorating components, monitor the rate of deterioration, while automatically scheduling service calls and ordering of spare parts, where required. In the extenuating circumstance, where the deterioration of one or more components compromises the safety of the consumer, the apparatus is able to shut-down.

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Description

Title of Invention: Scalable Autonomous Energy Cost & Carbon Footprint Management System

Technical Field

[1] This invention relates to the use of technology to create a Smart Grid of distributed equipment operating as stand alone, or in a cluster without limitation to size or number, in unison or individually to manage energy cost and carbon footprint of its users.

Background Art

[2] This invention is a panacea to high electricity cost and environmental pollution resulting from the generation of electricity, from inefficient fossil fuelled, peaking power plants i.e. often Open Cycle Gas Turbines, older less efficient Steam Turbines and in some instances Diesel, and even Heavy Fuel Oil Power Plants. The use of inefficient power plants to generate peak hours energy, together with the poor utility of electricity transmission and distribution assets, exacerbate the higher fuel cost problems, to render electricity unaffordable. The consequences to the society's vulnerable, the aged, and the unwell are dire. Notwithstanding, this inefficiency represents valuable capital in monetary terms of inordinate amounts, which may be put to substantially better use.

[3] This invention is not alone in attempting to resolve the problems of yesteryear; On the contrary, it is one of many dissimilar inventions attempting to resolve the common pain of our time, e.g., US Pat. No. 7,582,985 by Jose Murguia defines an invention that time sequences the commencement of energy consuming appliances, such that maximum demand is managed. US Pat. No. 4,520,259 by Frederick Schoenberger defines an invention that regulated the load on electric laundry dryers and hot water heaters. US Pat. No. 7,783,390 by Craig Miller defines methods for optimising the control of energy supply and demand. US Pat. No. 5,274,571 by Bradley Hesse et. al. features an energy storage scheduler. US Pat. No. 6,185,481 by Kirk Drees defines a real-time pricing controller for an energy storage medium to provide environmental conditioning. US Pat. No. 6,718,213 by Denis Enberg defines a method of load-side management, wherein variable base load energy consumption is selectively managed. US Pat. No 7,606,639 by Wendell Miyaji defines a method for reduction in energy consumption by remote, wherein the duration for which the downstream load connected to the device is permitted to operate for a limited time, defined by the remote signal.

[4] Intl. Pat. No. WO2010/103650 by Koyanagi defines an apparatus which stores power in DC, and distributes it to many consumers as AC power. Intl. Pat. No.

WO2010/135937 by Luo et.al. defines an apparatus for storing energy as means to balancing the load of a power grid. Intl. Pat. No. WO2010/089607 by Bowes et.al. defines an apparatus to manage and control the supply of energy to a load, using a rechargeable energy store. Intl. Pat. No. WO2010/086843 by Ko defines a system and apparatus to increase the availability of electrical power. Intl. Pat. No. WO2008/125697 by Cooper et.al. defines a load management controller for use in a household electrical installation. Euro Pat. No. EP2017937 by Buehler et.al. defines an invention for configuring and operating an energy storage system for supporting electric power networks during instantaneous network supply demand discrepancies. Euro Pat. No. EP2017937 by Ohler et.al. defines a method for using and operating batteries in to store energy to and from the grid. Euro Pat. No. EP2190097 by Paice et.al. defines a time dependent method for operating an energy storage system, where the charge/discharge schedule is achieved through time dependant forecast of the storage system and the power system, based of historical data.

Disclosure of Invention

Technical Problem

[5] High electricity cost and environmental pollution resulting from the generation of electricity, from inefficient fossil fuelled, peaking power plants i.e. often Open Cycle Gas Turbines, older less efficient Steam Turbines and in some instances Diesel, and even Heavy Fuel Oil Power Plants. This coupled together with poor utility of electricity transmission and distribution assets is a global problem for most Utility Companies worldwide. However, the environment of high energy cost, in an era of where the consequences of Greenhouse Gases are well understood and legislation against same is established, is perhaps the greatest impetus yet to change the way electricity is consumed globally. A change that has become necessary.

[6] The above inefficiency has today become a greater burden to most households and businesses globally, a trend if allowed to continue will render this situation untenable, with possible disastrous consequences. As an example, the average household monthly electricity bill in the UK was only £299 in January 1995, however in November 2011 this rose to an alarming £472. Thus electricity prices have increasing at a rate of 3.09% per annum over the intervening period. At the same time the average household monthly income in the UK, in 2011 was £519, having risen only 1.9% per annum on average, between 1995 and 2011. Ignoring entitlements, benefits and other social support mechanisms, the divergence of the two parameters will eventually result in disaster, if not sooner.

[7] The use of inefficient power plants for peak hours energy generation, together with the poor utility of electricity transmission and distribution assets, requires rethinking of

how electrical energy is availed to the the consumer and a need to separate in time, the purchasing of electrical energy, from when it is used. This is the only way to moderate the energy demand curve, from one that is saddled with numerous peaks and troughs, to one that is more evenly distributed throughout the day.

[8] Moderation of the energy demand curve in the context suggested above, shall require voltage and frequency support at the consumer's threshold, or on the same electricity distribution circuit. Such voltage and frequency support should ideally be linked to the demand experienced by one or more consumers.

Solution to Problem

Technical Solution

[9] This invention addresses high electricity cost, environmental pollution from the generation of electricity, from inefficient fossil fuelled, peaking power plants i.e. often Open Cycle Gas Turbines, older less efficient Steam Turbines and in some instances Diesel and even Heavy Fuel Oil Power Plants, together with the poor utility of electricity generation and distribution assets, and the need to reduce usage of both, financial and environmentally expensive peaking power plants, to manage peak electricity demands, necessitating a need for Scalable Autonomous Energy Cost & Carbon Footprint Management Systems.

[10] The technology embodied in this invention can operate :-

[11] (i) In a cluster within the same electricity distribution circuit, or in multiple unrelated electricity distribution circuits, within close proximity or at great distances between the members of the cluster;

[12] (ii) As one or more single units, operating independently without any collaborative support to each other, with or without optimisation criteria defined; and

[13] (iii) At the command of a master controller in the context of a high-level constraint setting grid dispatch centre, or as independent decoupled units working to local optimisation of its user's constraints, if at all any.

[14] The invention reduces CO_2 footprint of the electricity consumed by its user, by selectively purchasing during periods when CO_2 per kWh is within the optimal or desired range, thereby reducing the user's CO_2 footprint without buying more expensive Green Energy.

[15] The invention is scalable and autonomous, and can be used with self-learning algorithms to optimise and operate without intervention. The invention can also operate with point of use energy regulation to provide complex autonomous energy and carbon footprint measurement and management. The autonomy of this invention extends to the invention deciding how best to perform the routine and automatic function of consuming electrical energy for storage at self-determined times, which may be

defined as, including, but without limitation, times which are advantageous, convenient, inexpensive, off-peak, discounted or by any other term of terms that differentiates it, from the period in which the stored energy is to be utilised by the consumer.

[16] The invention separates in time, the act of procuring electrical energy from the act of using it, thus providing consumer discretion, over when in time electricity is bought, as opposed to, when it is used. Such discretion may be governed by including, but without limitation to economic, environmental or indeed other priorities. Separating the act of procurement from the act of usage, allow the invention to optimise multiple constraints governing discretion, against benefits resulting from exercising such discretion.

[17] The invention uses intervening methods of power conversion, to convert power from the Utility Interface to levels suitable for storage of electrical energy in media of choice including, but without limitation to batteries, and vice versa where stored energy is to be used by the consumer.

[18] The energy consumed may be stored in any energy storage system, including but not limited to battery or electrochemical systems, inertial systems, thermal systems, electrostatic systems, magnetic systems, such that stored energy may be used at a later time, for any purpose including, but without limitation to purposes of reducing cost, environmental and other pollution, burden placed by the consumption on the system delivering it, or indeed to support the system delivering it, at a time in the future, when the system may need such support.

[19] The invention transfers the power of purchasing electricity to the user; Such that the user is able to take control of the price at which electricity is bought as opposed to subscribing to one of many, forward consumption based Utility Companies schemes. This invention is able to optimise the purchasing of electricity during least cost hours, such that the energy purchased is stored for use later, as and when required.

[20] Although the energy consumed in this invention may be stored in any energy storage system, this embodiment of the invention disclosed herein employs the electrochemical and electrostatic storage system.

[21] The invention is performs self-diagnostics on itself and where necessary schedules automatic maintenance on a remote server and issues a service alert all relevant parties. This invention minimises downtime and outage by automatically scheduling service calls, escalating service alerts and ordering spare parts as internal operating conditions diverge from reference. It also provides routine reports to the consumer with regard to its operation, the consumer's energy consumption amounts and pattern together with suggestions and recommendations as and when required.

[22] The invention enables distributed frequency and voltage regulation of electricity grids, thus preventing brown outs and nuisance trippings, in weaker grids.

[23]

[24] DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

[25] The Scalable Autonomous Energy Cost & Carbon Footprint Management System item **23** in **Figure 1,** in accordance with the present invention is connected between the Utility Interface item **18** and the Consumer Load item **22**, in **Figure 1**. This will be described in greater detail below, and the Scalable Autonomous Energy Cost & Carbon Footprint Management System item **23** in **Figure 1,** in accordance with the present invention is used to alter the time at which electrical energy is bought, as opposed to when it is consumed, thereby providing the impetus for reduction in the cost of energy and the carbon footprint of energy consumption for single or multi-phase application.

[26] The Scalable Autonomous Energy Cost & Carbon Footprint Management System item **23** in **Figure 1** can be configured to provide energy management and storage, functionality suitable for use with Utility Interfaces comprised of any voltage and frequency, even Direct Current (DC) Interfaces. Popular Alternating Current (AC) embodiments are envisaged ranging from low voltages of 100 VAC up to 253 VAC for single phase and 200 VAC to 480 VAC for 3 phase installations, at either 50 Hz or 60 Hz. The invention is infinitely scalable, although present popular embodiments, envisage communication network infrastructure limit of 4,294,967,295 units per 1km radius. Therefore, as a result of scalability, the invention can be used to support substantially large consumer loads of varying sizes and configurations. Multiple units can provide as much power, as required.

[27] The Scalable Autonomous Energy Cost & Carbon Footprint Management System (hereinafter interchangeably used with the term 'System(s)') item **23,** in accordance with the present invention with reference to, **Figure 1**, commences operation by sampling the parameters of the utility interface to examine if any protection flags item **3** in functional block **1**, in **Figure 2**, to include, but without limitation to Over Current, Earth Fault, Over Voltage etc., are active, and if so, if and only if, all such flags are cleared, the System begins by first ensuring the switch **20** which may be to include, but without limitation to isolating contactor, relay or simply a switch is closed, thereby providing supply to itself and the consumer load **22.**

[28] The System commences operation by rectification of power from the Utility Interface after having filtered it through the mains filter, item **1** in functional block **32** in **Figure 2** which is parallel with transient and surge protection devices to include, but without limitation Gas Discharge Tubes, Transient Suppression Diodes, Metal Oxide Varistors etc. Metering circuits' item **2**, in function block **1**, in **Figure 2**, comprised of current transformer and isolated voltage divider network is interposed between the mains filter and the rectifier.

[29] Post rectification, power is driven into the DC link capacitor bank, providing

smoothing of ripple and voltage support by means of temporary storage, before DC current and voltage are metered by a suitable current measurement device, and isolation amplifier circuits, which provided current, and voltage measurement, item **5**, in functional block **33**, in **Figure 2**. These measurements are fed to an analog to digital converter, to be sampled as digital inputs to the microprocessor item **26** in **Figure 2**, and used to provide inputs to a back up a set of analog current and voltage regulation circuits, which act as redundant protection tripping inputs, in the event of a micro-processor fault.

[30] The now rectified, metered and smoothed DC current at the Utility Interface RMS Voltage level is further protected by fast acting high rupturing capacity fuses before manifesting at the inverter bridge, item **4**, in block **33** in **Figure 2**, where it is modulated into pulse currents of either variable or fixed duty cycle, square waveforms at a desired frequency. The electronic driver circuits item **6**, in functional block **33** in **Figure 2**, are switch-able between driving sinusoidal waveforms and square waveforms by the microprocessor, item **26** in **Figure 2**. The modulated pulse currents are then fed into a switchmode transformer, item **9**, in functional block **34**, in **Figure 2** to result in pulse currents of alternating nature, however now at the much lower voltage level commensurate with the typical requirements of storage media, to include, but without limitation to batteries, capacitors etc., vide item **30**, in **Figure 2**.

[31] However, between the switchmode transformer and the storage media terminals, lie interposed in series and parallel a rectifier item **8**, in functional block **34**, DC link capacitance item **7**, in functional block **34**, buck-boost converter item **10**, in functional block **31**, series parallel reconfigurator item **11**, in functional block **31** and adaptive charger item **12**, in functional block **31**, in **Figure 2**. The rectified DC current exiting the DC link capacitors in item **7**, in functional block **34**, is available at the desired low voltage DC level, depending on the Utility Interface RMS AC Voltage.

[32] The reconfigurator, item **11**, in functional block **31**, in **Figure 2** performs the function of numerous interconnected switches, which are energised in a predetermined manner to automatically disconnect or connect a circuit which was previously inter-connected in either series or parallel configuration. The Reconfigurator is used to change a previous configuration to one that is usable during charging or discharging, depending on whether the System, requires in this case the elements within the storage media to include, but without limitation to be connected in series or parallel to meet the required voltage or current rating.

[33] The adaptive charger, item **12**, in functional block **31**, in **Figure 2** takes into account the present state of charge in the storage media, in this embodiment battery, through specific gravity of the electrolyte. Based on this assessment, together with other input parameters, to include, but without limitation to voltage, the amount of energy

discharged during the immediate preceding cycle, the profiles of voltage, temperature, current and energy vs. time during the immediate preceding discharge cycle, number of cycles operated, present temperature of battery, ambient temperature around the battery etc. the adaptive charger performs a multi-parameter optimisation, to result in the best charge regime to employ, in order to maximise the amount of energy stored in the battery at the end of charging cycle, without affecting the longevity of the battery. The impact of a particular charging regime is known apriori from prior research in terms of probability ascertained from statistical analysis of large sample size and stored in the database. Prior to computing the optimisation algorithms, the parameters observed are aged, using a mathematical model to allow the observation of time sensitive change in operating parameters.

[34] This variable voltage is regulated by the buck-boost converter item **10**, functional block **31**, in **Figure 2**, to the required voltage levels suitable for use to charge the storage media bank, which includes, but without limitation batteries which are charged individually via the adaptive charger mechanism item **12** in functional block **31,** in **Figure 2**., where the batteries are charged appropriately through bulk, absorption, trickle phases of battery charging. The adaptive charger in order to achieve all three phases of charging operates in both voltage and current mode as and when required.

[35] All through the operation of the System, component parameters to include, but without limitation to implied parameters, such as, voltage, current, frequency, capacitance, resistance, inductance, temperature, specific gravity etc., are measured, digitised, sampled and analysed by the microprocessor, encrypted and transmitted in summary terms to a central database, functional block **27** in **Figure 2, 3** and **4**. E.g. parameters associated with the charging process of storage media to include, but without limitation to battery, such as voltage, current, temperature, specific gravity etc., are continuously monitored and stored for troubleshooting and trend analysis, as illustrated in functional blocks **51** through **61** in **Figure 4**. Such component parameter tracking is performed on each and every primary component or element within the System as a whole, functional block **51** and **53**, in **Figure 4**, for any indication of variance beyond limits specified by the manufacturer, or accepted operating limits stored in the database. The database, functional block **27** in **Figure 2, 3** and **4**, storing such operating parameter performance also contains the serial, and batch numbers of each and every component used in every System that is built. Therefore, the operating performance parameters are cross-referenced to the component serial and or batch numbers to provide the basis for wider statistical analysis, functional block **53** and **55** in **Figure 4**, and insight into potential component premature failure, functional block **58** in **Figure 4**, albeit operating stress induced, under design anomalies or manufacturing failure. Detail analysis is carried out in function blocks **58** and **59** in **Figure 4**

, along with the respective decisions in functional blocks **56** and **57** in **Figure 4**, to ascertain if the rate of change of the component parameter variance is rapidly deteriorating, or if the component failure is a prior identified failure mode, if so then immediate and urgent action is impressed upon the Service and Parts Interface to expedite the replacement as soon as possible. In the event the impending component failure could compromise the safety of the consumer functional block **60** in **Figure 4**, then the System will impress such danger upon the Service and Parts Interface, before shutting itself down functional block **61** in **Figure 4**, but allowing the microprocessor functional block **26**, in **Figure 2** and Communications module functional block **28** in **Figure 2**, to continue communicating with the Service and Parts Interface. The availability of such data also aids the process of managing product liability and defect warranty issues expediently, as well as to ensure supply chain pitfalls do not hinder consumer utility of the System.

[36] The charging process, once commenced will continue until either the System has reached the sufficient level of charge predetermined by its optimal control system, or indeed if it has reached the maximum amount of charge that may be stored in its storage media, item **30**, of **Figure 2**, which may be determined by the threshold mode of control within the System, or indeed if the external real-time clock intervenes as set up by the microprocessor within the System, signalling the need for the System to change from charge to discharge status, where the power hitherto flowing from the Utility Interface item **18** of **Figure 2**, is disconnected item **20**, of **Figure 2**, and the energy hitherto stored within the System is then used to supply the consumer loads. The discharge cycle commences with the series parallel Reconfigurator, item **14**, in functional block **31** of **Figure 2**, configures itself such that the elements within the storage media, which in this embodiment batteries and electrostatic storage, are setup in the predetermined series and parallel configuration to provide the required level of voltage and current necessary for the System to support the consumers load.

[37] The power flowing out of the storage media flows to the inverter bridge item **10**, in functional block **35** of **Figure 2**, which is modulated using fixed duty cycle pulses of variable or fixed frequency, before being fed into a switchmode transformer item **9**, in functional block **34**, of **Figure 2**, such that power in the storage media is now at a voltage level which is suitable for conversion into AC voltage which may then be fed to the consumer load, at the same specification as would otherwise be available through the Utility Interface.

[38] Prior to flowing through the inverter bridge, power originating from the storage media is metered through a Hall effect device to ascertain DC current flowing through, and a resistive network to measure DC voltage, item **11**, in functional block **35**, of **Figure 2**. The power flowing through the switchmode transformer item **9**, in functional

block **34**, of **Figure 2**, is rectified and fed into the DC link capacitors, item **7**, in functional block **34** of **Figure 2**, which performs the duty of smoothing the rectified pulse currents and providing short-term storage.

[39] The power flowing through the DC link capacitors will then be further smoothed by a inductor before passing through another Hall effect device, item **5**, in functional block **33**, of **Figure 2**, where the DC current passing through is metered and a voltage divider network, where the DC voltage of the link prior to being driven through a fuse and then on the inverter bridge item **4**, in functional block **33** of **Figure 2**. During the discharge cycle, item **4**, in functional block **33**, of **Figure 2** will be suitably modulated as desired using Sine wave data points at any chosen frequencies, with the fundamental frequency of the relevant Utility Company Standard, typically 50 Hz or 60 Hz, thus providing Sinusoidal 50 or 60 Hz current flowing through the AC mains filter, item **1** of functional blocks **32** in **Figure 2**, which includes filters to remove the harmonics.

[40] Power flowing out of the inverter bridge, pass through AC current and voltage metering which is done through a current transformer and a set of resistive networks, item **2** in functional block **32** of **Figure 2,** before finally leaving the System via the surge protection devices comprising of Gas Discharge Tubes, Transient Voltage Suppression Diodes and Metal Oxide Varistors.

[41] Immediately prior to the surge protection devices, System Fault Protection Measurements are carried out, comprising over-voltage, under-voltage, over-current, earth fault, over-frequency and under-frequency, item **3** in functional block **32** of **Figure 2**. Zero crossing detection is also performed at this point, and communicated to other Systems in the same circuit, thus allowing other units which are in working the same circuit as this System to synchronize frequency and phase, such that collectively the Systems are able to support larger load on the given circuit.

[42] The microprocessor is assisted by real-time clocks providing accurate timing reference and alarm annunciators to the System, with include annunciation at regular intervals, to the communications module, thus enabling the microprocessor to link itself and the System with external databases and the outside world through the use of TCP/IP protocols, and in so doing, the microprocessor shall up-date itself with weather in the local area, to include the near-term forecasts, pricing and other information related to the Utility Company, currently contracted to supply the consumer, the CO_2 per kWh emissions related to energy generated for the Utility Company, operating parameter databases, service schedules and service alert databases and email and short message service sub-systems. There are multiple external databases, operating in real-time synchronous mode, but at different sites, with different addresses. Therefore, in the event of a failure of one site, hosting one or more databases used by the System, it can turn to another site, hosting up to date copies of the same databases, and yet

another site and so on. The System is autonomous in real-time, in that it shall decide for itself based on the information it has access to, how to operate and what to do. It does this by applying the appropriate mathematical, statistical or computational models, to arrive at the best decision, in regard to timing for the commencement of consumption of electrical energy and discontinuance thereof.

[43] The Scalable Autonomous Energy Cost & Carbon Footprint Management Systems can operate in threshold, optimised forecast based and direct, or remote control mode. Each mode is described in the following paragraphs, where necessary with the aid of flow charts.

[44] The threshold mode is useful for consumers who have no desire to optimise, but charge up the entire storage capacity, of the Scalable Autonomous Energy Cost & Carbon Footprint Management System everyday, during the off-peak or other preferred hours, such that energy stored is available for the consumer's use thereafter. In this mode the System does not optimise, but rigorously charge up the storage capacity, on the assumption that the full reserve capacity of stored energy, is to be made available for use by the consumer, and that the consumer has either analysed the cost and carbon footprint, or that cost and carbon footprint are not priorities, consequently the predetermined times for commencement and discontinuation are to be implemented.

[45] Variation of the threshold mode, programmed to be triggered on reaching threshold e.g. 'CONSUME IF $CO_2 < 350$ gCO_2/kWh' is also available. The threshold may be electricity price, carbon footprint or indeed, any other variable that may be referenced to on-line, and one that the consumer could point the user interface to, during setup. The threshold mode may be set to commence, discontinue or toggle state when the selected variable reaches programmed threshold. E.g. 'DISCONTINUE IF $CO_2 >= 450$ gCO_2/kWh.'

[46] The Scalable Autonomous Energy Cost & Carbon Footprint Management System offers optimisation of selected constraints, to include, but without limitation to two forecasting modes. Both forecasting modes support goal seeking (e.g. minimisation of error between prediction and outcome) and use linear and non-linear models to achieve the objective. The first of the two modes, is suitable for use when the model used for forecasting is overspecified, which is when a large number of correlated (i.e. explanatory) variables are available, to be related to the objective parameter to be forecast. Such models include, but without limitation to Generalised Least Squares. The second mode, is suitable for use, when the model used for forecasting is under-specified, which is when insufficient number of correlated variables, are available to be related to the objective parameter, to be forecast. Such models include, but without limitation to non-linear regression based on the Gaussian Process. Both forecasting

modes support self-learning and continuous improvement by constantly goal seeking, to minimise error between forecast and actual performance.

[47] The forecasting modes, functional block **40** in **Figure 3**, are used to include, but without limitation predict, near and medium term electricity prices and CO_2 emission per kWh, based on any variable that may be correlated, e.g. Oil, Gas & Coal Prices, Weather patterns, Planned events could impact supply and demand of Electricity etc. Forecasting modes require substantial processing power, consequently, the forecasting models are run on the Energy Information Server, functional block **27** in **Figure 2** and **Figure 3**. The consumer is able to configure the forecasting models, as desired, through the user interface, functional block **41** in **Figure 3**, and select single or multiple variables to drive the forecasting process, and if desired, link the forecast variable to the optimisation algorithm. The consumer also has the ability to introduce external datasets using industry standard Comma Separated Variable (.csv) files. The following examples illustrate.

[48] 'PRIORITY CONSTRAINT = MONTHLY ELECTRICTY COST =< $235;'

[49] 'CONSTRAINT = CO2 < 45KG;'

[50] 'FORECAST ERROR = 0.1%;'

[51] 'FORECAST PRICE = FX{GAS PRICE, WEATHER};

[52] In the above example, the System analyses the consumer's historical energy consumption, functional block **42** in **Figure 3**, based on all available intra-day consumption data to date, identifying trends in the underlying consumption pattern before calculating the most likely average daily consumption going forward during the optimisation period above, and the associated minimum and maximum cost boundaries, i.e. forecast the cumulative daily consumption and calculate the worst case and best case estimated energy cost for the optimisation period, which will then be compared against the target constraint desired (hereinafter known as 'target'), functional block **44** in **Figure 3**. If the worst case estimate is lower than the targeted $235, it will compute the difference between the worst case estimate and the target, and run a second set of forecasts, however this time adversely affecting the variables GAS PRICE and WEATHER, such that it minimises the difference between worst case estimate and the target, functional block **47** in **Figure 3**. This variance is then transmitted to the consumer, as the margin available, notwithstanding which, the target stands achievable. Further, since, CO_2 is also selected as a constraint, albeit not the priority constraint, it too like electricity prices, will be forecast. For as long as the difference between consecutive worst case estimates and the set target, either remains the same or increases, the System will seek to consume energy, at a time when the CO_2/kWh is forecast to be the least. Here too the consumer has the ability to setup variables involved in and the method of forecasting, as in the case for electricity pricing. The

secondary constraint will become the focus, provided the priority constraint is achievable i.e. the difference between the worst case estimate and the target, or when the likelihood of achievement is the same as it was in the past or improving.

[53] The System will reiterate by repeating all of the steps above, functional blocks **45** through **50** in **Figure 3**, each time the data point in any of the underlying variables (i.e. Gas Prices and Weather in the above example) electricity prices, CO_2/kWh, and in the event, the difference between the worst case estimate and the target is positive, or if the probability of the best case estimate becomes less then a predetermined threshold set by the consumer, the System will advice reduction in consumption of electrical energy, such that the likelihood of achieving the target set, improves and the System will iteratively demand reduction in consumption, until eventually the target set is met. In the event the target set is unrealistic, defined by the difference between the best case estimate and the target being positive, the System will provide representation, to include, but without limitation to simulated graph of consumption levels that need to attained, if the target is to be met, as a means to communicate the possibility of a mistake being made, in target setting. The System assumes that it is perfectly acceptable to set demanding targets, which may require reduction in energy consumed, if the target is to be achieved.

[54] The selection of the forecasting modes is automatically made by the System, by separating the variables selected into two datasets. The first dataset used to train the forecasting engine and the second to test the now trained forecasting engine for conformity, by measuring the average and variance of the error, between the predicted outcome by the forecasting engine and the actual outcome in the second dataset. The training parameters are adjusted, until the average error and variance of the forecasting engine exceeds that set by the consumer i.e., 0.1% in the above example. The System will automatically discern if the parameter to be forecast is underspecified or overspecified, by the underlying variables selected, and in either case choose the appropriate mode. If the System fails to adjust, the training parameters such that the average error and variance exceed that set by the consumer, it will automatically try the alternate mode, whereupon continued inability to meet the error target set by the consumer, may result in changes made to the underlying variables, if deemed necessary.

[55] The direct or remote control mode serves to allow the consumer to intervene while operating in either the threshold or optimised modes, and in so doing the consumer may toggle the state of operation from one to the other. The consumer is able to do this remotely via secure password protected access using the internet, email or cellular short message service. When the consumer places the System in direct or remote control mode, it is possible for the consumer to specify if this change is to remain until

the next intervention, or if it should remain active for a limited period of time in days. Special access variant of the direct or remote control mode is available for the Emergency Services, where in the event of a fire or other perilous circumstances require to the System to shut-down etc.

Advantageous Effects of Invention

Advantageous Effects

[56] This invention provides impetus for a paradigm shift by allowing the consumer to control the price at which electricity is bought. Beyond enabling the consumer to buy electricity at the lowest possible rates (i.e. during the hours when the demand for electricity is least), the Scalable Autonomous Energy Cost & Carbon Footprint Management System also addresses several vital issues hitherto unresolved by allowing the consumer to control the price at which electricity is bought, vis-à-vis :

[57] (a) Improving the utilisation of Utility Company assets, which are sized to generate and distribute more than the forecast peak electricity demand i.e. in the case of Great Britain, 77% of the 81,632 MW installed capacity, but often generates and distributes not more than 25 to 40% of the 81,632 MW installed capacity during the off-peak hours from 11pm to 7am; and

[58] (b) Reducing the CO_2 footprint of electricity generated by the Utility Company, without investing in Green assets or buying in Green energy. The CO_2 footprint can range in the case of Great Britain between 600 gCO2/kWh during the height of peak electricity demand period (7am to 11pm) down to below 260 gCO2/kWh during the lull of off-peak period (11pm to 7am).

[59] The use of Scalable Autonomous Energy Cost & Carbon Footprint Management System shall give rise to substantial reduction in Electricity Grid's peak demand and increase in off-peak demand thus, considerable flattening of the base load scenario, which shall give rise to:

[60] (i) Increased use of high efficiency generating plant such as Combined Cycle Gas Turbines (CCGT), conversion of some Open Cycle Gas Turbines (OCGT) to become high efficiency CCGT base load plants etc. thus increasing efficiency, reducing cost and CO_2 footprint of electricity;

[61] (ii) Less frequent requirement to use traditional peaking power plants often in the form of Open Cycle Gas Turbines, Diesel (to include Heavy Fuel Oil) Power Plants and less efficient and older Coal Fuelled Steam Power Plants. This will also reduce the CO_2 footprint from electricity generation; and

[62] (iii) An opportunity to retire some of the expensive (both financially and environmentally) peaking power plants, and the saving gained may offer increased roles for Renewable Energy, investments in Energy Efficiency etc.

[63] The Scalable Autonomous Energy Cost & Carbon Footprint Management System will also be useful to the Utility Companies in improving frequency and voltage regulation and also to prevent brown outs and nuisance tripping, besides enabling the consumer to minimise their carbon footprint in accordance to the desired level of CO_2, without having to invest in alternative energy or pay more for Green Energy from the Utility Companies.

Brief Description of Drawings

Description of Drawings

[64] The present invention is best understood in conjunction and with reference to the following drawings and accompanying descriptions, wherein:

[65] Figure 1 describes the main functional blocks of an embodiment of the Scalable Autonomous Energy Cost & Carbon Footprint Management System.

[66] Figure 2 describes in schematic form the detail functional blocks of an embodiment of the control and instrumentation of Scalable Autonomous Energy Cost & Carbon Footprint Management System.

[67] Figure 3 describes the information flow and decision points related to the optimisation control, of an embodiment of the Scalable Autonomous Energy Cost & Carbon Footprint Management System.

[68] Figure 4 describes the information flow and decision points related to the auto-diagnostic and service management system, of an embodiment of the Scalable Autonomous Energy Cost & Carbon Footprint Management System.

[69] Figure 5 describes in block schematic form the power conversion an embodiment of the Scalable Autonomous Energy Cost & Carbon Footprint Management System.

Best Mode for Carrying out the Invention

Best Mode

[70]

Mode for the Invention

Mode for Invention

[71]

Industrial Applicability

[72]

Sequence Listing Free Text

Sequence List Text

[73]

Claims

[Claim 1] CLAIM OR CLAIMS

[Claim 2] The present invention is not limited to the particular embodiments and applications herein illustrated and described, but embraces all modified forms thereof, than the scope of the following claims. What is claimed is:

[Claim 3] The Scalable Autonomous Energy Cost & Carbon Footprint Management System for any and all electricity consumer comprising:

a. Means of obtaining electricity pricing data to include but without limitation to real-time electricity pricing and carbon footprint information;

b. Means of discriminating commencement and discontinuation times to consume electrical energy from the Utility Company based on including but without limitation to optimising constraints to include but without limitation to reduction of cost and carbon footprint, as methods of discrimination;

c. Means of detecting and measuring parameters of power conversion including, but without limitation to voltages and currents of the various power conversion stages within the system and the monitoring of operating in the event they occur, such that protection of the consumer and system are ensured;

d. Means of converting the power consumed from the Utility Company, by using including, but without limitation to

i. Reversible power conversion, which has the advantage of minimising components otherwise required; or

ii. DC/DC, AC/DC, or DC/AC Conversion; or

iii. Conventional transformer type conversion; or

iv. Any other type of power conversion Utility Interface voltage levels and storage apparatus voltage levels, and vice versa.

e. Means of charging the storage media, with power consumed from the Utility Company including, but without limitation to adaptive charging of batteries and capacitors used in this embodiment of this invention;

f. Means of storing the electricity consumed from the Utility Company, such that it be used by the consumer at later time, but with benefits including but without limitation to having procured it at favourable or advantageous cost and carbon footprint;

g. Means of converting the power stored in the storage media which

was previously consumed from the Utility Company, at the time of convenience and utility to the consumer by using including, but without limitation to:
i. AC/DC power inverters; or
ii. Conventional power transformers; or
iii. Any other type of power conversion to step up the voltage of the energy stored in the storage media to that of the Utility Interface voltage levels.
h. Means of synchronising multiple Smart Electrical Energy Management & Storage Systems to support larger loads;
i. Means of communicating all performance and operational information including but without limitation to the consumer, external systems etc; and
j. Means of monitoring operating parameters against reference and calibrated data to identify anomalies and trends, and acting on same to schedule maintenance, escalate service alerts and order spare parts.

[Claim 4] The method of claim **3a** wherein data pertaining to electricity pricing and carbon footprint information may be stored in any data structure to include, but without limitation to database, tables, one, two or multiple dimension arrays etc. In either electronic or any other form which may or may not be rated the transmitted or made available via real-time electronic media. The method of claim **3a** is extended to, information that may be transmitted via storage media of any form, paper or networks to include, but without limitation to cellular, wireless, wired etc.

[Claim 5] The method of claim **3b** where the means of discriminating time of commencement and discontinuation, shall include, but without limitation to look up table searches to make logical and arithmetic deductions from data, application mathematical, statistical, computational analysis. The method of claim 1b, when necessary may also include the use of predictive models to include without limitation statistical, logical, mathematical, computational etc.

[Claim 6] The method of claim **3c** includes, but without limitation the use of detection and measurement electronics which include but without limitation to instrumentation amplifiers, resistive networks, voltage dividers, analog to digital converters, current transformers, Hall effect devices, positive or negative coefficient resistors etc.

[Claim 7] The method of claim **3d** of this embodiment comprises a mains filter unit with common mode chokes and associated capacitors to comprise a low pass filter with gas discharge tubes and transient suppression diodes across the input of the mains filter, with fuses in series and negative temperature coefficient resistance before going through a current transformer and then being rectified prior to charging a bank of ripple smoothing and short-term storage capacitors and a limiting choke to trap any remaining high-frequency ripple components. A Hall effect device measuring current prior to a second fuse and a full bridge inverter where the current is pulsed through the full bridge inverter into a high-frequency switch more transformer to result low voltage power which is rectified measured and managed to maintain regulated low voltage, before being used to charge into the battery storage units.

[Claim 8] The method of claim **7** of this embodiment refers to inverter bridge which comprises to include, but without limitation, plurality of driver circuits and switches for multi-phase performance in the form of including, but without limitation to IGBTs, MOSFETS etc.

[Claim 9] The method of claim **7** which refers to regulating low voltage power before being used to charge storage media, in this embodiment batteries and capacitors, are routed through a buck boost converter, whereby the voltage is either raised or lowered to suit the adaptive charging regime requirements as the charging process progresses through the various phases.

[Claim 10] The method of claim **3e** and **9** where the means of determining the adaptation of the charging rates appropriate for the storage media used, to include, but without limitation to batteries, commences with the measurement of the specific gravity, or the state of charge, of the electrolyte, which is derived by means of either direct measurement or by implication arising from the measurement of internal resistance of the storage media, in this embodiment batteries. The information arising from the computation of the specific gravity of the battery provides the microprocessor with information regarding the state of charge of the storage media, which in turn is information used to compute parameters of the appropriate charging mechanics to include bulk, absorption, trickle phase. The parameters together with the temperature measurement of the storage media will provide the necessary impetus to compute the voltages and currents that pass through the storage media, through the various charging phases for predetermined durations.

[Claim 11] The method of claim **3f** wherein the microprocessor through the information that it collects and resolves in accordance to claim **4**, performs checks against the data that it has, to confirm that the energy presently stored in the system which is to be used by the consumer at a later time, is indeed used at the time when including, but without limitation, the cost of the energy and or the carbon foot print of the energy from the Utility Company, at that time at the of consumption, by the consumer, is more disadvantages to the consumer then including, but without limitation, the cost and carbon footprint of the energy presently, stored in the system, at that time it was consumed.

[Claim 12] Method of claim **3e** wherein the means of charging the storage media to include, but without limitation batteries and capacitors as in this embodiment, does so by separating the plurality of storage in two or more numerous devices of individual electrical connection, and in this configuration, treats each and every such device individually, in regard to the process of performing measurements across and through such devices, and the act of charging the devices.

[Claim 13] The method of claim **3g** wherein the means of converting energy stored in the storage media which was previously consumed from the Utility Company, commences with the predetermined interconnection of the storage devices, either in series and or in parallel, in order to achieve a predetermined voltage and or current capability required of the system, before being connected to a current measurement device, to measure the current passing through to the inverter bridge which pulses the current passing through to the switch-mode transformer resulting in the current being transformed to a higher voltage, suitable to achieve the appropriate interfacing level prior to transfer of power to the consumer, at the same specification as that of the Utility Company. The power transfer to the consumer commences once the utility interface has been disconnected by a switch of a type to include, but without limitation to isolating contactors.

[Claim 14] The power leaving the inverter bridge in claim **13**, now at a voltage level suitable for interfacing with the consumer, with the same specification as the Utility Company, is first rectified, prior to flowing into a ripple removing and short-term storage capacitor bank, followed by an inductor before passing through another Hall effect device, measuring the current following through it, before flowing to the final inverter bridge. The final inverter bridge is modulated suitably to result in current flow at including, but without limitation to standard Utility Company frequencies. Modulation techniques used may include the integration of several frequencies to result in low distortion, harmonic free alternating current, commensurate with legal specification for power suitable for use by electrical appliances.

[Claim 15] The method of claim **13** and **14** of this embodiment, of this invention refers to an inverter bridge which comprises to include, but without limitation plurality of electronic and driver circuits for switches for multi-phase performance in the form of including, but without limitation to type and configuration e.g. IGBTs, MOSFETs etc.

[Claim 16] Voltages throughout methods of claim in this invention to include, but without limitation to claims **3** through **15** of this filing, are constantly measured through a network of signal attenuators followed by one or more filters prior to being digitised in analog to digital converters, which is then sampled at chosen number of times each second. The sampled voltage measurements are read by the microprocessor, as a means amongst others, to make real-time control decisions, therefrom.

[Claim 17] The method of claim **3h** in a scenario, where more than one Scalable Autonomous Energy Cost & Carbon Footprint Management System, is required to support loads, larger than any one unit is able to, on its own, in the absence of a single unit amongst many, with the largest amount of stored energy, a single unit is identified through a self selection process, whereby a random number is assigned to each unit, and based on a simple arithmetic process, one among many units is automatically selected to lead the process of synchronisation. The unit selected to lead the process of synchronization, will send out a zero crossing beat, which shall be used by all other units working in unison, as the signal against which the each unit will individually synchronize.

[Claim 18] The method of claim **17** wherein the synchronisation signal is transmitted to other units using including, but without limitation to wired, wireless, cellular, radio frequency networks.

[Claim 19] The method of claim **17** and **18** wherein multiple synchronized clusters of Scalable Autonomous Energy Cost & Carbon Footprint Management Systems, can coexist within the same electrical network, on different phases where each cluster consisting of multiple units supporting individual loads, or individual groups of loads of substantial size, without interfering with other clusters on different phases in the same distribution circuit.

[Claim 20] The method of claim **17** wherein the synchronization of multiple clusters of Scalable Autonomous Energy Cost & Carbon Footprint Management Systems can coexist, in multiple sites, on a common distribution network, linked to the same point to include, but without limitation to the secondary side of a distribution transformer, such that the units can be set up to be synchronized and support events such as to include, but without limitation brown outs, black outs, transients, disturbance etc. thereby, providing protection to the consumers using such clusters against these events. Such clusters shall be synchronized to the grid of the Utility Companies, as such these units will be constantly online but without transferring power effectively acting as standby units waiting for an event such as those defined above, to intervene by transferring power almost instantly into the grid to support it during occurrence of such events thereby protecting the consumer.

[Claim 21] The method of claim number **3i** wherein the Scalable Autonomous Energy Cost & Carbon Footprint Management Systems communicates with information sources including, but without limitation to servers, databases, client programs etc., through the use of any means including, but without limitation to wired, wireless, cellular, radio frequency etc. networks. Such communication may use encryption and decryption, in order to satisfy the degree of protection of such information demanded by consumers and or legal requirements. The encryption and decryption techniques used may include, but without limitation to SHA-1, AES 128, 256, 512 etc.

[Claim 22] The method of claim number **3j** wherein the Scalable Autonomous Energy Cost & Carbon Footprint Management System detects, measures and monitors change in component operating parameters, regularly and routinely against calibrated data and reference data of such component parameters, obtained during initial setup and as advised by the respective component manufacturers via information freely available in the public domain or obtained through private correspondence. The measurement of operating parameters is typically obtained from including, but without limitation to direct measurements of currents, voltages, resistance, temperature, capacitance, inductance, etc.

[Claim 23] The method of claim **22** is achieved by means of conducting measurements of such, parameters frequently through the use of electronic networks, to include, but without limitation to Hall effect devices, current and voltage transformers, voltage dividers, comparators, amplifiers, negative and positive temperature coefficient resistors etc., whereupon the measurements are filtered appropriately prior to being digitised via analog-to-digital converters, to be sampled frequently by the microprocessor, to determine including, but without limitation the severity of variations, trends in variation, rate of change of variation such that these events and the underlying data may be statistically and computationally analysed to conclude and predict its impact to present and future performance.

[Claim 24] The method of claim number **22** wherein the Scalable Autonomous Energy Cost & Carbon Footprint Management System, communicates with information sources including, but without limitation to servers, databases, client programs etc. through the use of any means including, but without limitation to wired, wireless, cellular, radio frequency etc. networks, to expedite including, but without limitation to the scheduling service calls, escalating service alerts, informing the consumer and others, of impending maintenance requirement with emphasis on the severity and urgency of such service requirements, the ordering of spare parts etc. to minimise impending downtime, resulting from an inevitable service event.

[Claim 25] The method of claim **11** wherein the means of storing electrical energy is achieved by using a combination of one or more storage media, such that the combination results in improved performance, over each individual member of such a combination in isolation. An example of such a combination may include, but without limitation to lead acid batteries, super capacitors and lithium ion or lithium polymer batteries, whereas the combination of all three of the above can demonstrably improve, performance over the use of any one of the three in isolation.

[Fig. 1]

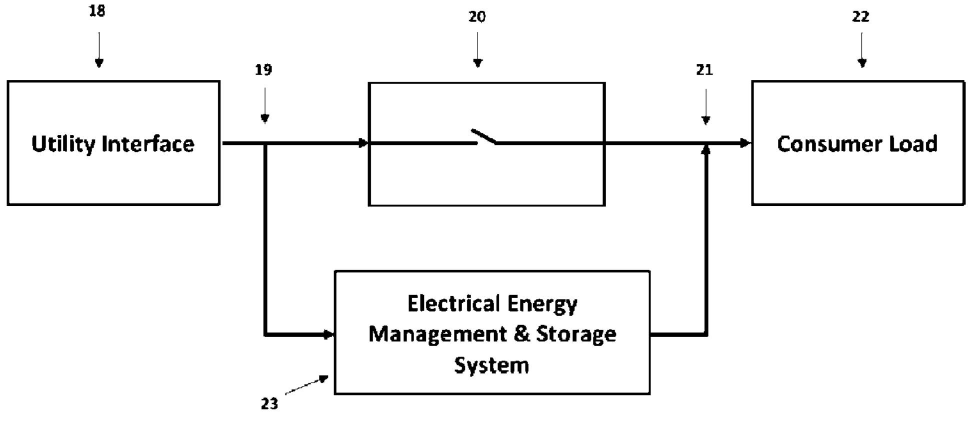

Figure 1

[Fig. 2]

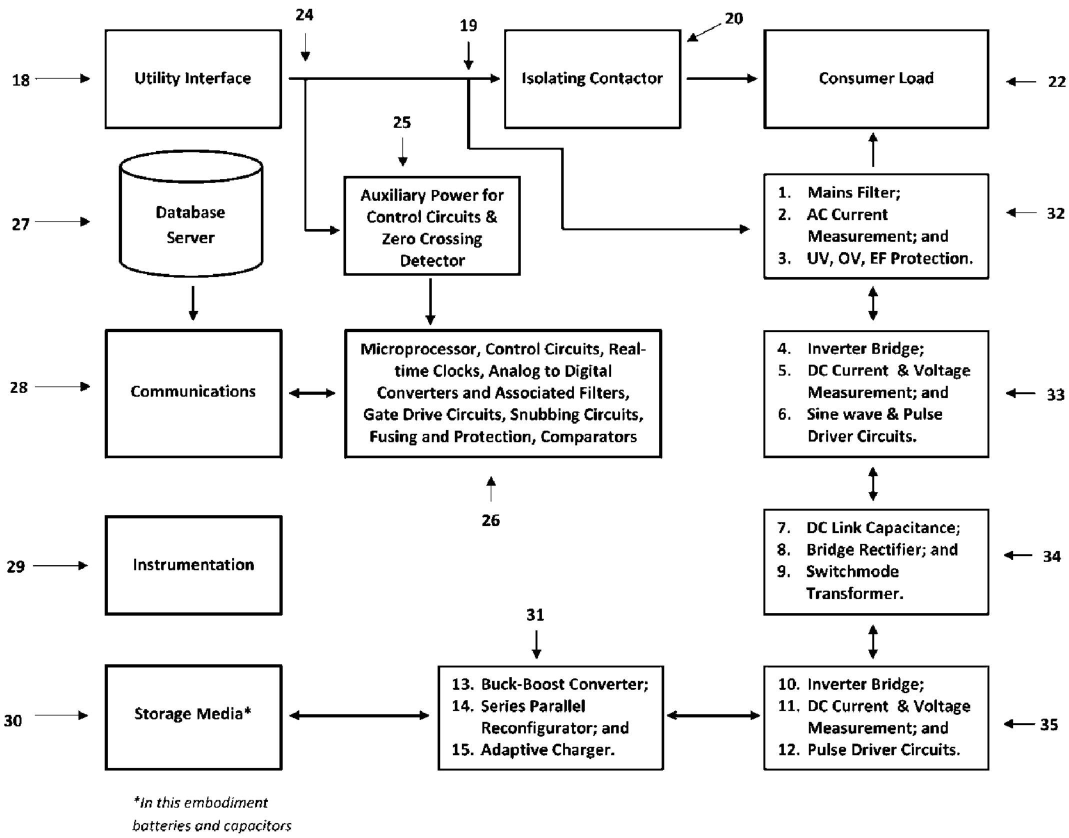

Figure 2

[Fig. 3]

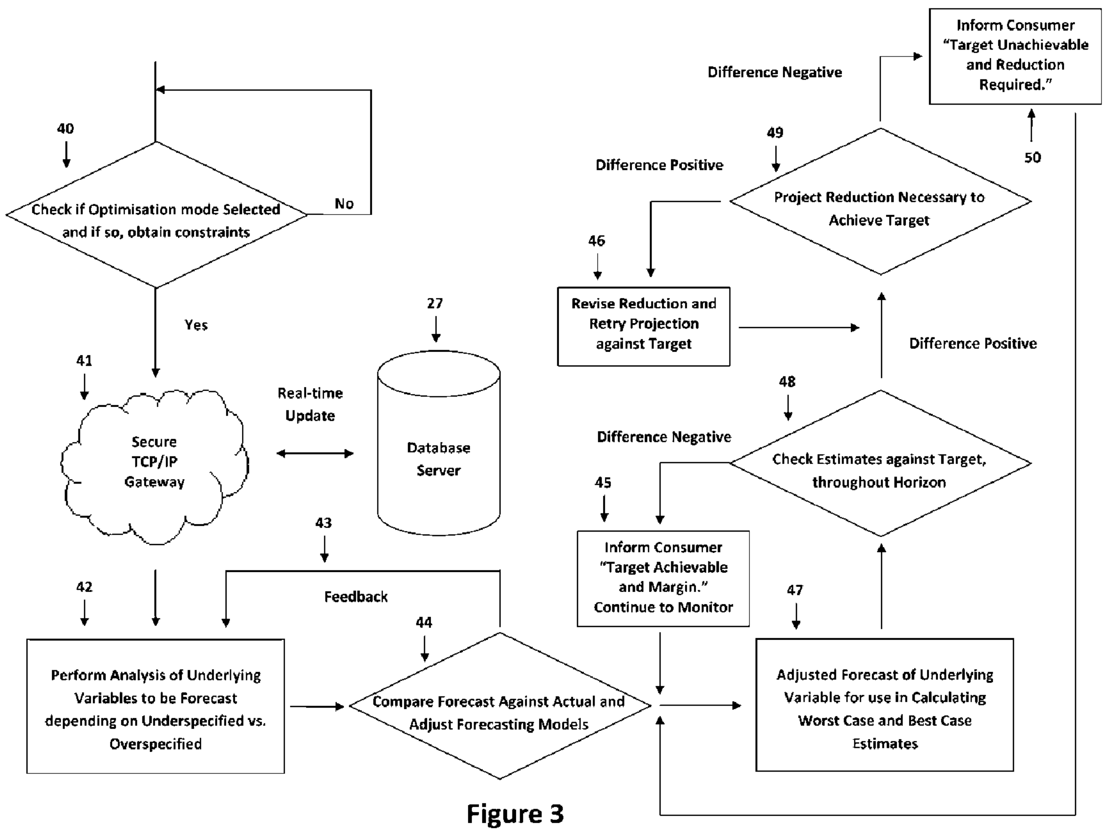

Figure 3

[Fig. 4]

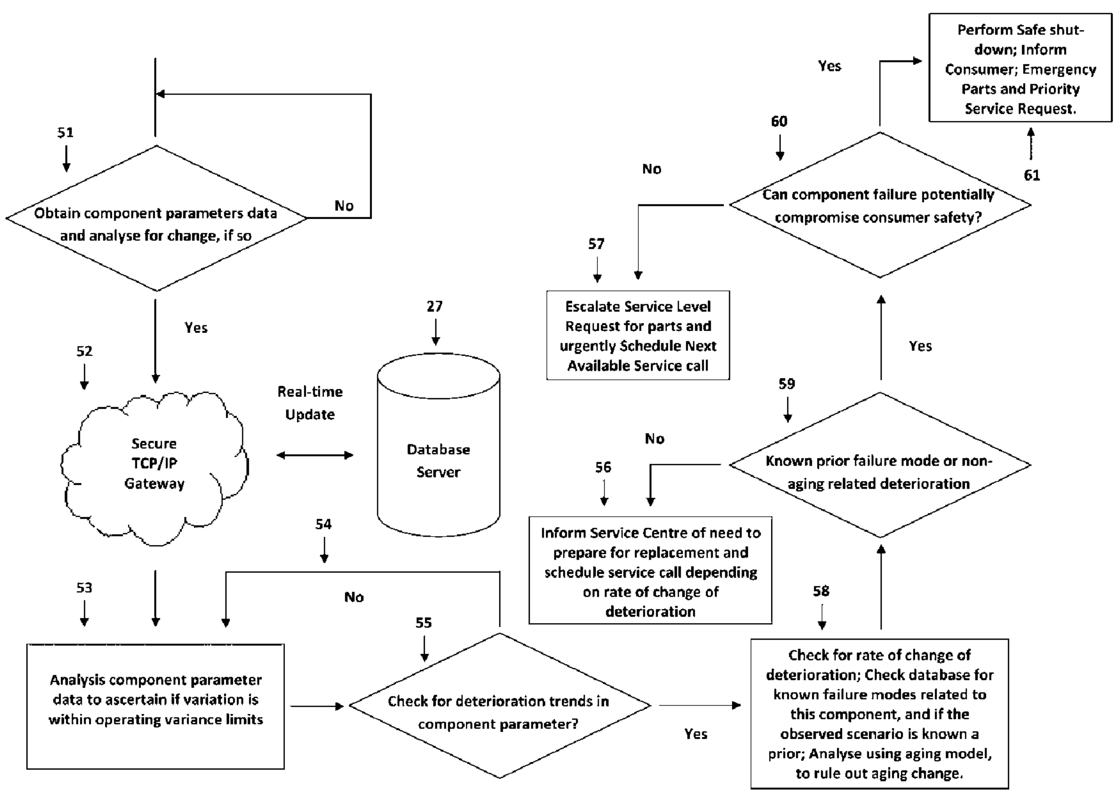

Figure 4

[Fig. 5]

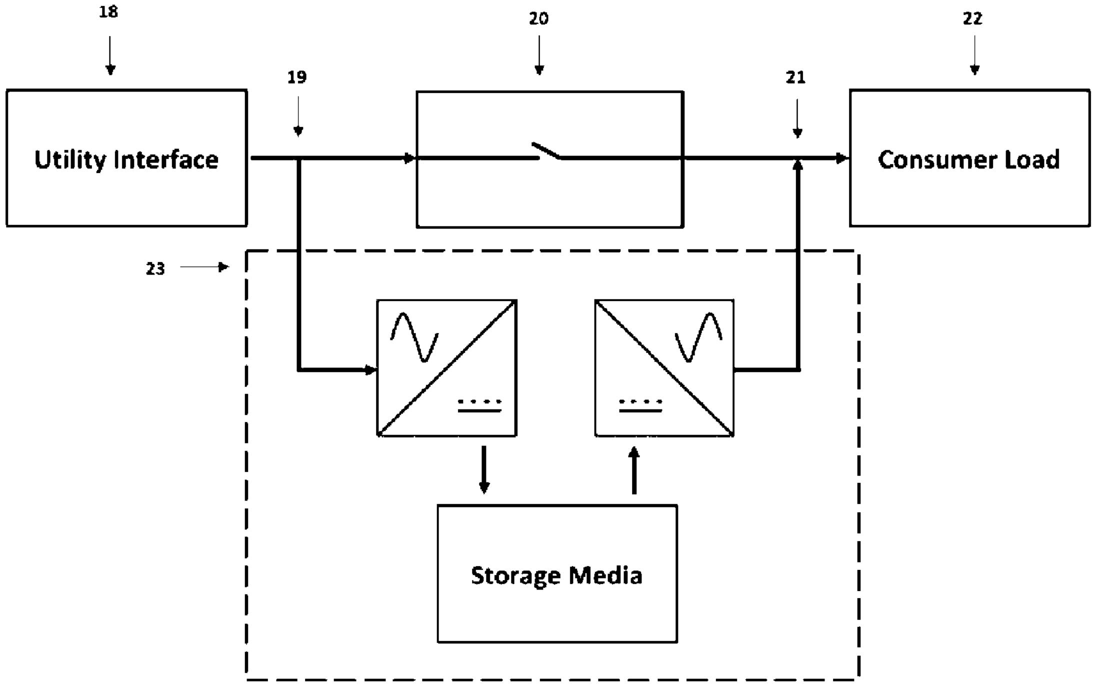

Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2012/051102

A. CLASSIFICATION OF SUBJECT MATTER

H02J 13/00(2006.01)i, G06Q 50/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02J 13/00; G08C 15/06; G01R 21/133; G08B 1/08; G08B 21/00; G08B 23/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: scalable, energy cost, monitoring, converting, storing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6553336 B1 (JOHNSON ROBERT N. et al.) 22 April 2003 See the abstract; claim 1; figures 1-2.	3
A	US 4568934 A (ALLGOOD; MARVIN D.) 04 February 1986 See the abstract; claim 1.	3
A	US 5736847 A (VAN DOORN; PETER M. et al.) 07 April 1998 See the abstract; claim 1.	3
A	US 4262287 A (MCLOUGHLIN; JOHN et al.) 14 April 1981 See the abstract; claim 1; figure 1.	3

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 OCTOBER 2012 (10.10.2012)	**12 OCTOBER 2012 (12.10.2012)**

Name and mailing address of the ISA/KR
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Facsimile No. 82-42-472-7140

Authorized officer
WEE Jae Woo
Telephone No. 82-42-481-8540

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2012/051102

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6553336 B1	22.04.2003	None	
US 4568934 A	04.02.1986	EP 0080504 A1	08.06.1983
		EP 0080504 A4	18.09.1985
		US 4415896 A	15.11.1983
		US 4512033 A	16.04.1985
		US 4608560 A	26.08.1986
		US 4648123 A	03.03.1987
		US 4933633 A	12.06.1990
		WO 82-04492 A1	23.12.1982
US 5736847 A	07.04.1998	CA 2148075 C	20.03.2001
		US 6185508 B1	06.02.2001
US 4262287 A	14.04.1981	None	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2012/051102

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1-2, 4-25
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

As claims 1-2 do not clearly define the matter for which protection is sought, these claims do not meet the requirement of PCT Article 6. The term "claim 3a", "claim 3b", "claim 3c", "claim 3d", "claim 3e", "claim 3f", "claim 3g", "claim 3h", "claim 3i", "claim 3j" used in claims 4-25 are vague and unclear, thereby rendering the claims 4-25 unclear.

3. ☒ Claims Nos.: 10, 15, 16, 19
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.