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(56) Documents Cited:
WO 2009/141651 A2
WO 1998/041793 A2
CN 102025155 A
US 6081104 A
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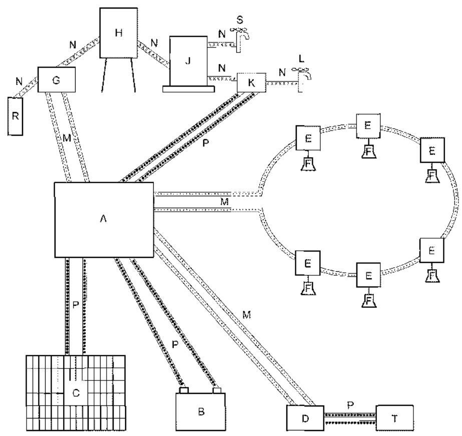
(58) Field of Search:
INT CL **H02J**
Other: **EPODOC, WPI**

(54) Title of the Invention: **Micro SmartGrid Off Grid Community Electricity System**
Abstract Title: **Direct current power transmission grid**

(57) A micro-grid supplies, regulates and transmits power to multiple consumers using direct current (DC) transmission. The grid can include: power management and communication hub A providing maximum power point tracking charging and protection for battery B; photovoltaic array C, and possibly a wind turbine or generator powered by diesel, gas or pedal; and consumer units D and E handling power for LED lighting F, water pump G, power tools and battery chargers. Battery B can be protected by inactivating or reducing supply to loads by pulse width modulation according to a priority transmitted to smart consumer units D. The priority can be overridden by a key. The DC grid can be connected to a similar DC grid for power sharing or to a conventional AC grid via a meter and can add smart grid features such as response to power balancing commands and providing power from batteries upon request. The grid can be used in rural communities in off-grid areas, to provide power from renewable sources for lighting, charging mobile phones, laptop computers and to pump and treat water.

The Micro Smart Grid

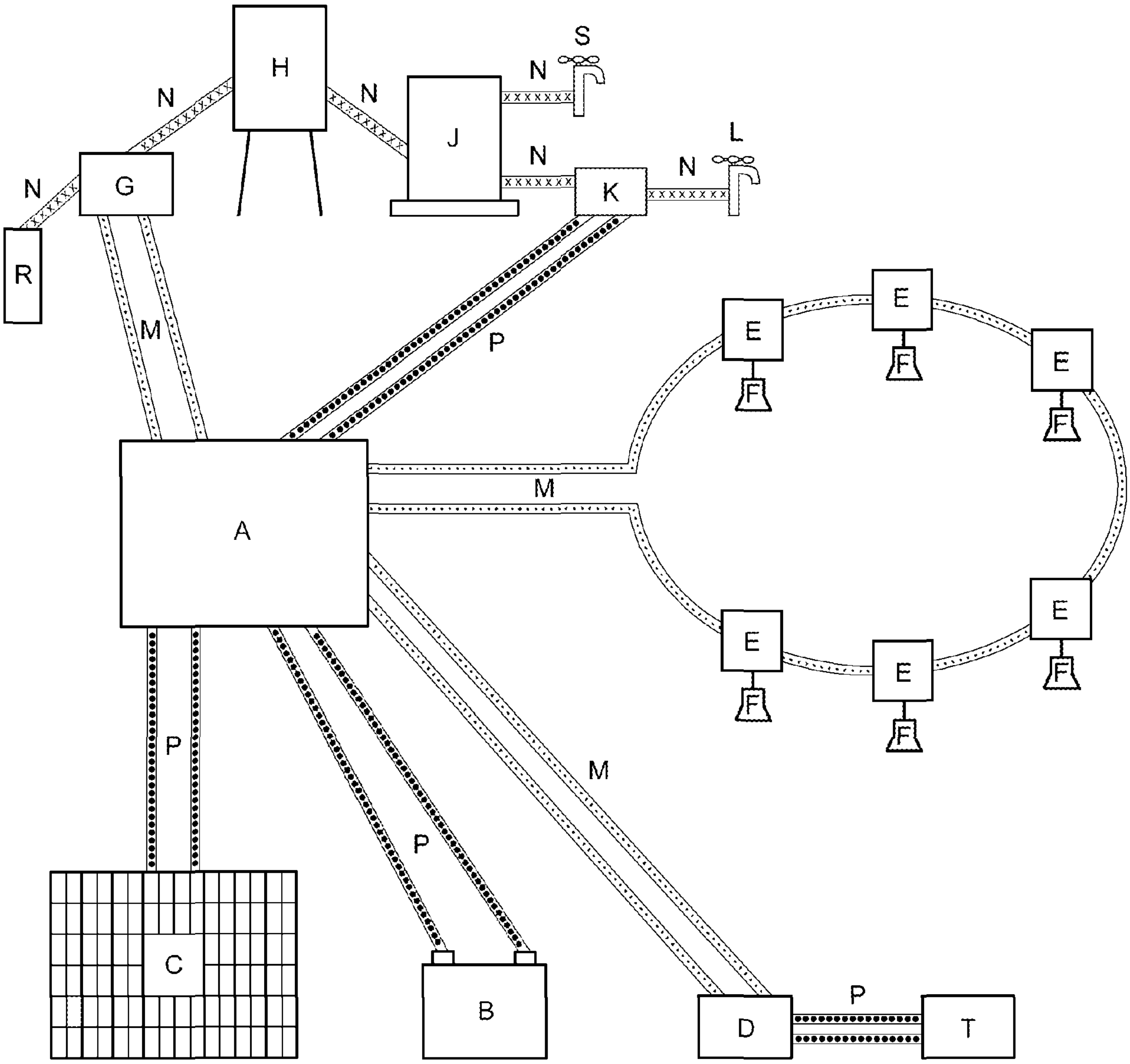
Figure 1 of 1



GB 2482114 A

The Micro Smart Grid

Figure 1 of 1



Micro SmartGrid Off Grid Community Electricity System

The Concept

It is already known that the standard of living and health of 3rd World Rural Communities could be substantially raised by the provision of an affordable electric system in off grid areas. The system would obtain its energy from renewable local sources, store power for night time use, and allow a range of services of vital importance to improving health, education, business opportunities and communications. Solar energy has been identified as being reliably available in tropical and sub tropical regions, and is likely to form the backbone of the power generation system. Such systems, as well as delivering a modest power supply to people to whom it has not been available, are able to offer environmental and social benefits.

In terms of environmental benefits, the system would significantly reduce the amount of fuel used for lighting, which at this time tends to be derived from paraffin, oil, candles, or a wood fire. As well as reducing CO2 emissions and possibly reducing the tendency to overexploit trees and other vegetation, the use of electric light will result in substantial reductions in indoor air pollution, which is a major cause of ill health and premature death in developing countries.

In terms of social benefits, improved lighting availability and affordability will bring greater opportunities to learn by reading, to hold classes in the evenings, and will make it easier to care for anyone who is sick. The availability of electricity for charging mobile phones and to run laptop computers will bring about a revolution in communications and trade with the ability to talk to friends, relatives, business contacts, etc. anywhere in the world from even the most rural of locations, to listen to radio, to watch television, to access the vast store of information available on the internet, to make business and other arrangements by E-mail, and to receive educational materials such as lesson plans from experienced teachers. In terms of water supply, electricity will enable water to be pumped to a header tank from which it can flow through a low technology low cost sand filter which removes the majority of parasites and bacteria which can contaminate water bringing ill health to the community. If desired or necessary in the specific location, this water can then be passed through further filtration processes, or treated with Ultraviolet light to bring it up to drinking water standard. It should be noted that filtration / treatment can be applied to remove harmful substances such as arsenic as well as biological agents from water. Arsenic is present in ground water in large areas of Bangladesh, and many adjacent areas of India. Electricity will also enable the use of small electrically powered tools and machines such as soldering irons, small electric drills, sewing machines and the like which will greatly increase the range of opportunity for running small scale rural businesses.

It is proposed that a sophisticated lighting and power system could be developed to provide 3rd World rural communities with the facility of basic room illumination, and small appliance charging in individual dwellings. Additional facilities would be available at community level such as the provision of a local pumped and filtered water supply, and use of a more extensive range of electrical appliances such as television, laptop computers, community access to the internet, and power for electric tools used in community workshops. This system is managed by an intelligent network to provide a consistent service to the local community of dwellings, and to community Micro Industries. For example a community workshop could use rechargeable tools which are recharged intelligently by the power network backed up by rechargeable batteries either at each dwelling or in a central battery pack.

In some rural locations other renewable energy sources might be available such as wind, hydro power, or small scale wave energy generation (available in rural coastal communities). These renewable energy sources could be fed into the intelligent power network for the benefit of the whole community, or even be supplemented by pedal driven generators.

It is proposed that the majority of the system be unmetered to individual users as the system at individual home level is primarily designed for lighting. As lighting will be provided using LED lamps which have exceptional energy efficiency, electricity consumption by each lighting only customer will very low – so justifying the lack of a meter. There is the possibility to incorporate higher output facilities for business or community customers some of which may be of sufficient size to justify metering. There are social implications to the use of a shared unmetered power system, and these are likely to be best managed by a small cohesive community. In such a community, the common good is likely to be more firmly seated than in larger more westernised communities, and peer pressure will ensure that each person acts responsibly to ensure that everyone gets their share of power when it is needed.

Rationale for using an intelligent power network

By connecting systems together across a small rural community, power can be shared – so that for example, on weekends, and school holidays when the school is shut, power collected by the school can be used for lights in the Church or Mosque or for domestic uses.

Some components of the system are more cost effectively available at larger sizes. Examples include high quality deep cycle lead acid batteries or alternative battery options as well as photovoltaic arrays and high efficiency solar chargers.

A community Micro SmartGrid system will enable water to be pumped up from a well or borehole, passed through a filtering / purification process, and delivered as safe drinking water through one or more communal taps.

Using larger photovoltaic panels and locating them in one place reduces the amount of labour needed to deliver a given amount of power, and also facilitates regular cleaning.

Allows prioritisation of power delivery – so that using a Micro SmartGrid, power might reach lights in a health clinic or school at higher priority than a domestic dwelling. This allows lighting brightness to be turned down or lights turned off in homes whilst keeping good illumination for essential services.

Allows for allocation of priority based on a key – so that, as an example, the community birth attendant might carry a key which gives priority in a home where she is delivering a baby.

Ensures that a larger proportion of power collected can be put to good use. In separate systems without interconnections some users will end up with full batteries effectively switching off their panel whilst someone else has battery capacity available or unsatisfied power demand.

Interconnected systems will cope better with occasional momentary high loads such as from a water pump or power tool, so “adding value” to the community as a whole.

Allows for interconnecting nodes where each panel array and battery pack is connected via a cable to other nearby systems allowing transfer of power between Micro SmartGrids.

By intelligently dimming lights and selectively switching off outlets such as phone chargers when battery charge is low, a degree of illumination is maintained for considerably longer than could be achieved without such intelligence.

If a Micro SmartGrid were to be connected to an expanding mains electrical system via an inverter, the system would be capable of conferring some of its smart features to the mains. The system would achieve this by continuing to regulate power consumption on those items connected to the Micro SmartGrid - when needed by dimming lights and switching out non urgent demand at peak times, by offering the facility for the community to run “islanded” off grid during power outages, and by assisting with power balancing by exporting power at peak times, and storing power at off peak in existing battery facilities.

The Micro SmartGrid System

In order to obtain the maximum possible set of advantages from a limited supply of power from photovoltaic panels or other renewable sources, the following units are to be formed into a system containing the following components and features.

Photovoltaic panels and or other low carbon power sources which can be expanded to match growing need.

Standardised power regulating subsystem box to contain all electronics allowing panels, other power sources, batteries or load to be connected to the system using standardised connectors. There may be one or several standardised subsystem boxes on any one Micro SmartGrid.

Maximum Power Point Tracking charge controllers to regulate the most efficient possible transfer of power from panels or other power sources under varying conditions to battery storage or load.

Optional inverter to supply mains power to one or more outlets, and to allow that later, if the community were to be connected to the mains grid, that power could be imported or exported as necessary.

A system power supply controller to send out signals down an earth wire or otherwise via the power wires, by WiFi, Bluetooth or other wireless connection to instruct programmable consumer units in how to deliver power to loads.

LED lights set up to be dimmable using variable duty cycle pulse width modulated control or alternative means of achieving the same end. The lights to be dimmed when necessary in response to centrally generated signals in response to varying battery charge state, or manually dimmable by the consumer if a light of reduced brightness is preferred. In addition, lights could be switched off automatically during daylight using a light sensor connected to the central supply unit, or individually switched off using infrared sensors if a room is unoccupied, or automatically dimmed if no one is moving about.

Power supply conditioners in each consumer unit to deliver pulse width modulated power to LED lights, allowing downward adjustment of lighting brightness by adjusting the duty cycle as battery charge state reduces. These consumer units to be controlled by the control system (4) and programmed to get the best possible use out of finite stored electrical power (Better a dimmed light than none). Where services other than lights are offered by the consumer unit, these are also under the control of the control system so that if battery levels are low, other appliances may not be allowed to operate. E.g. mobile phone charging which might only be permitted with full or nearly full batteries, or in the hours of daylight.

Power outputs offered at each consumer unit at different voltages to run LED lights, charge mobile phones, run small radios, or at particular locations, laptops small televisions etc. Alternatively, each basic domestic consumer unit serves lighting loads only, and enhanced consumer units with the additional features described are aimed at community or business customers.

Deep cycle Lead Acid batteries to store power, other options which would serve are flooded Nickel Cadmium, Zebra Sodium Nickel Chloride, Nickel Metal Hydride, Lithium Ion, Vanadium Flow Cells or Zinc Bromide flow cells. In regards to Lead Acid, a single high quality deep cycle lead acid battery offers greater longevity than multiple lower quality batteries, and has lower maintenance requirements. Standard Lead Acid batteries do not tolerate frequent deep discharge, and even deep cycle can be damaged by complete discharge, so management of state of charge is vital to battery life. Batteries are also vulnerable to high temperatures.

A battery enclosure of porous hollow blocks filled with sand is proposed to allow for evaporative cooling (or alternative designs of similar function). By keeping the sand wet, evaporation significantly reduces the average temperature inside the enclosure, and prolongs the life of the batteries. (This type of enclosure might not be needed for other battery systems).

Supply regulation to allow progressive load reduction as batteries are discharged, i.e. switching out non essential uses first, then dimming lights stepwise as batteries are further discharged until the battery contains only a 20% state of charge or such other level of charge as is decided from time to time is the minimum reserve capacity allowable, at which point the system is switched off to protect the batteries.

Sensors to be placed to estimate as closely as possible battery temperature, with this information feeding into the supply unit algorithm which determines how much the battery can be permitted to discharge before reducing power consumption / switching the system off.

3 core cables with positive, negative and signal wires. An alternative option would be to use 6 core cable which would allow later connection to a conventional grid with cables 4 & 5 set aside for carrying AC power, and 6 as an earth wire. Cabling arrangements could be via rings, or spurs, with as many of each as are needed to keep line resistance losses within acceptable parameters.

Prioritisation algorithms permitting prioritisation by location, or by an override key in the event of low battery charge state. This will allow vital supplies such as those to a health clinic even if domestic supplies have to be reduced or cut off.

Simple micro-processor controls to intelligently control all aspects of charging and power delivery.

Designed to start small and expand to a limited degree. (Beyond a certain size, more conventional systems begin to take over), however the system remains useful even if a conventional grid expands to connect the community, as it provides secure always available power for lighting, and adds smart capabilities to a mains power supply.

In order to provide a degree of protection for the investment, an alarm can be set up to provide warning if the connection between the batteries or main supply box and a photovoltaic panel is broken, so reducing the risk of theft of the more expensive system components. The alarm can also be configured to warm of system faults

As a feature of the system, and the many measures taken to ensure delivery of high quality services using a very modest amount of power, it is possible to deliver sufficient power at very modest voltages – not more than, and probably significantly below 50 volts without excessive resistive losses in the transmission cables. This renders the power supply much safer than a mains voltage AC power cable which can deliver a dangerous possibly fatal electric shock.

A key feature of the Micro SmartGrid is the ability to integrate a water subsystem to pump water making it readily accessible from one or more taps in a communal locations without repeated trips down to the well or stream, and to treat water by sand filtration, by chemical or biological precipitation to settle out contaminants, and by ultraviolet light treatment or other available methods where necessary so making it safe for drinking.

The Micro Smart Grid - Key to Figure 1

A. The power management and communications hub – Handles Maximum Power Point Tracking battery charging, delivery of power to loads on the Micro SmartGrid, and distribution of broadcast signals instructing consumer units on how to manage power.

B. Battery Pack

C. Photovoltaic Array – could also incorporate a wind turbine, pedal powered generator, or a conventional natural gas or diesel generator.

D. Enhanced consumer unit – handles a limited amount of power for a range of applications with smart control of loads to preserve power for essential services. This unit handles a wide range of power usages including LED lighting, water pumping, power tools, sewing machines, televisions, consumer battery charging – mobile phones, laptops etc.

E. Standard Consumer Units – handle power for LED lighting, smart features allow progressive dimming by pulse width modulated control.

F. LED Lights under pulse width modulated control.

G. Water pump – pumps water to a header tank, operates primarily when batteries are full, so providing an extra service when power can be spared. At times when power is in short supply, a manually operated pump can be used (not shown).

H. Water tank – sufficient capacity to last several days, so providing a buffer against dull days when less water is pumped.

J. Primary water filter – this filter most likely a sand filter providing basic primary water treatment. Water from this filter can be used for laundry, animals, and may or may not be fit for drinking.

K. Secondary filter – provides extra water purification for drinking water bringing it up to safe drinking water standard, could be ionic filtration, reverse osmosis membrane, ultraviolet light, or otherwise.

L. Drinking water tap

M. Power transmission lines with signal transmission over the earth wire or otherwise.

N. Water pipes.

P. Power cables without signal transmission.

R. Water source – borehole, well, stream or pond

S. Non potable tap – simple filtration is less costly to operate than full water treatment, so full filtration is reserved for drinking water.

T. Various loads on the Enhanced Consumer Unit – could include television, laptop computer, mobile phone chargers, power tools, sewing machine etc.

Claims

1. A Micro SmartGrid for a small community able to supply and effectively regulate transmission of power to ensure continued supply and battery protection whilst supplying multiple consumers with electricity by DC transmission.
2. A system which optimises battery life by enclosing lead acid batteries in an evaporative cooling enclosure.
3. A system with the capability of continuously monitoring state of battery charge, and of regulating power supplied to loads to protect the battery first by reducing supply at chosen set points using adjustable duty cycle pulse width modulation so protecting the battery.
4. A system with prioritised power delivery controlled by signals sent down a wire or transmitted using WiFi, Bluetooth or other means to smart consumer units allowing selective supply reduction to make best use of limited stored power.
5. A system which depending on battery voltage or alternative measure of charge state can adjust pulse width modulated or otherwise regulated supply sent to LED lights – so reducing brightness and power use.
6. A system which can selectively inactivate devices such as mobile phone chargers so as to preserve charge for lighting and other higher priority uses.
7. A system which can give different priorities to different users so that the supply of power is reduced first in low priority locations whilst maintaining full supply for longer in high priority locations such as health clinics.
8. A system with the facility to override the usual prioritisation using a key such as for a special event, or to allow a sick person to be cared for.
9. A system with the facility to intelligently manage battery charging using maximum power point tracking charge control or otherwise to optimise collection of power and battery life.
10. A system with the capability of collecting power from any or several of a variety of sources such as photovoltaic panels, small wind turbines, micro-hydro turbines, pedal powered generators or such other clean power sources as can be obtained depending on local resources for delivery via a micro-smart grid.
11. A system capable of sounding an alarm at the nearest consumer box in the event of a system fault or of the power source or battery being physically disconnected from the system – so offering a degree of protection against theft.
12. A smart DC micro-grid system designed to facilitate expansion of energy collection, storage, and consumer base, and interconnection with other similar systems nearby.
13. A system capable of connecting to a conventional grid on a net metered basis or otherwise – offering continued reliable provision of lighting and other low power devices once connection to the public grid becomes possible.
14. A system with the capability to add smart grid features to a conventional grid if interconnected with one, these features to include the ability to respond to the power balancing demands of the grid by storing power for the grid or delivering power to the grid from its batteries on request.
15. A system capable of operating as an uninterruptible power supply for on grid customers with or without autonomous power generation.
16. A system for supplying a modest amount of power across a DC micro-grid at low voltage without excessive resistive losses, so enhancing user safety in regards to electrocution risk.
17. A system capable of phased upgrade from basic lighting supply up to state of the art full service mains power delivery with integral power storage, integrated uninterruptible power supply, and demand side power management.
18. A system with the capability of integrating water pumping so making water more readily available without the heavy and time consuming work of fetching water from a distant well or stream.
19. A system integrating the capability to filter, to treat biologically, to treat chemically, or to treat using ultraviolet life water so rendering it of safe drinking water quality.

Application No:	GB1011936.0	**Examiner:**	Robert Barrell
Claims searched:	1 to 19	**Date of search:**	16 November 2011

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1 to 19	WO2009/141651 A2 (POWEROASIS) See: page 6, line 17 to page 10, line 32; and fig 1
X	1 to 19	US6081104 A (KERN) See: the abstract, fig 1; column 4, line 44 to column 8, line 49; and column 12, lines 36 to 45
X	1 to 19	US5477091 A (FIORINA et al) See: the abstract; figs 1 to 9 and column 2, line 41 to column 8, line 65
X	1 and 9 to 19	WO98/41793 A2 (NEXTEK POWER SERVICES) See: the abstract; page 7, line 19 to page 11, line 16; and figs 1 to 10
X	1, 10 and 12 to 17	US2008/0217998 A1 (PARMLEY) See: the abstract; paragraphs 0019 to 0026 and 0049 to 0069; and fig 1
X	1, 9, 10, 12 to 15 and 17	CN102025155 A (LIANG) See: the WPI abstract; and fig 1

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

H02J

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
H02J	0001/06	01/01/2006
H02J	0007/35	01/01/2006