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Proposed Integrated Design Model for Hybrid Micro Grid Based Green Homes

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Abstract*—ThispaperproposesanewIntegrateddesign model for hybrid micro grid based green homes. The proposed system can also be taken into use with little adjustments for residential townships, green data centres, commercial buildings, Educational Institutes, Hospitals. Renewable sources like Solar, Wind & Biomass Energy are selected for Hybridising thesystem which encourages ecofriendly environment. Two way PLCC based Energy meters and/or pre-paid meters help monitoring the power consumption from utility and electricity Power management Unit helps resulting in optimaldecisionsonenergyflowdirectionsisthekeyof this system. Based on pricing, renewable energy output, load demand, storage, and forecasting, decisions are made and communicated by the PMU. Such a system is capable to serve as an alternative power supply unit in cases of power cut, blackouts, grid failure, and peak demand, as well as results in minimum purchase from the AC utility Grid resulting in a low electricity bill. It ensures a better quality and continuity of power supply tousers.Italsoprovidesusers/customermultiplechoices to choose from, and decide on the optimalselection.The usage of renewable energy encourages and facilitates sustainable development. Green Energy Storage and multi-port dc/dc converters areencouraged.*

Keywords*- Renewable energy, Green storage, Hybrid μgrid,PLCCbasedenergymeters,Utility/gridinterface, Power ManagementUnit(PMU)*

I. Introduction

Intoday'sscientificeramostofourdailyneeds and utility depends on one or another form of energy. Out of which most of our utilities are dependent on electrical energy because of the usage of electrical and electronic equipments. Usually, standard AC grid or utility is the main source of electrical power. However, theavailabilityofthispowerislimited&isnotavailable in ample amount for everybody usage mostly in developing and undevelopedcountries.

Therefore, there are obvious power cuts to make a balance between the available power and the load demand. In addition to this some premium power consumers like Industries, Hospitals, are given more priorities over residential areas/communities. In such cases, residential areas should have their own alternative arrangement to meet their power requirements in frequent power cuts and blackout periods. On one side, wherein developing andunder- developedcountries,therenewableenergybasedenergy system has become a necessity, on the other side in developedcountries,thereisaneedforaback-upenergy system to avoid blackouts. Hence, Renewable energy technologies are receiving increased attention as an attractive electricity supply option for meeting electric utility needs in the1990sandbeyond. Theyhavetheirownenvironmental andsocio-economic benefits. This paperproposesanew Integrated design model for hybrid micro grid based green homes. The proposed system can also be taken intousewithlittleadjustmentsforresidentialtownships, green data centres, commercial buildings, Educational Institutes, Hospitals as and when required. Hybrid grid means a combination of low voltage DC and standard AC grid. Where in solar, wind and biomass energy system have been chosefor hybridization and supply DC via low voltage DC Grid. Most of the residential load is DC. However, we run them on AC with ac/dc power supply integrated with individual loads. This imposes power quality, harmonic losses, and energy efficiency issues. The proposed system introduces low voltage DC grid with multi-port dc/dc converters to supply dc loads and avoid such issues. And also enhanced quality of power can be supplied. Power Management Unit, start-up and shutdown logics, protections, sensor network, and communication unit are integral part of it. The layout of this paper is as follow: Proposed energy system with Hybrid energy sources is discussed in Section II. Green energy storage is discussed. Energy management based on pricing, available storage and renewable output is discussed in Section III. Power conversion systems for several nodes are discussed in SectionIV.

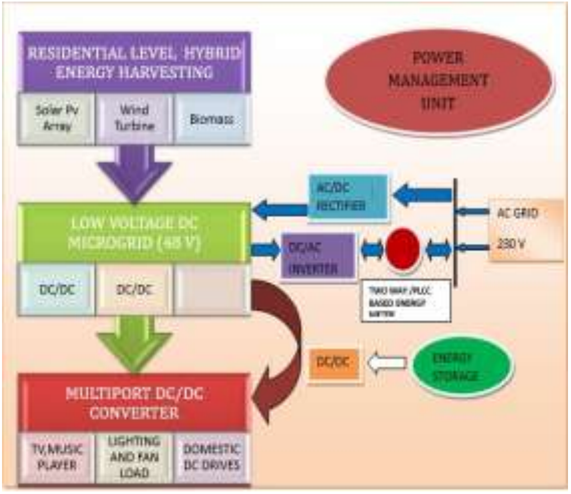

Fig. 1. Proposed Integrated design model for hybrid micro grid based green homes

II. Proposed Energy System With Hybrid Energysources

The harvested energy from the renewable energy sources such as solar, wind, biomass,geothermal ,wavesetc cannot be used directly but can be converted into utilizable electricity or heat. The energy drawn fromrenewableenergysourcesareconvertedintouseful ac/dc form by the usage of power electronics interface. For residential, commercial and industrial applications occasional sources like PV, wind, biomass have gained much acceptance. Fuel cell vehicles and inverters have earn demand for high efficiency and uninterrupted output. The most significant advantages of fuel cells are low emission of green house gases and high power density. Super capacitors, also known as ultra capacitors, are electrical energy storage devices, which offer high-power density and extremely high-cycling capability. On wind turbines they provide the adjustment of the blades in different wind conditions allowingformoreefficientenergyharvesting.Theseare the substitute against battery but are now not considered as feasible green options due to disposal issues. As of now Fly wheel energys to rage systems are takingaplace in the market and treated asviable.

Fig.1portraysaback-uppowergenerationsystemunder energy storage for flexibility. A storage unit helps to ensure a steady flow of energy from wind and sun, making it easier to respond to demand. Energy storage is a key element of advanced power flow management. Arelativelysmallamountofenergystoragecanbeused to minimize the rate of change of system output to the grid and avoid demand charges. Much more storage is required to provide significant capability for off-grid operation, unless other generation sources, such as an engine-generator,areavailable.Theproposedstoragein the form of gas is green and overcomes the drawbacks of battery / ultra-capacitor basedsystem.

Transportation electrification has gained significant interest and attention of researchers and industries owing to its merits of zero emission, positive impact on health and social life, as well as contribution towards clean and green atmosphere. The electrical energy storage units must be sized so that they store sufficient energy (kWh) and provide adequate peak power (kW) for the vehicle to have a specified acceleration performance and the capability to meet appropriate driving cycles. Much of the recent battery development has been concerned with high power batteries for hybrid-electric vehicles (HEVs) and not high energy density batteries for electric vehicles (EV). Recently, there has been considerable research on ultra-capacitors that use pseudo-capacitive or battery-like materials in one of the electrodes with micro -porous carbon in the other electrode.This is being donetoincreasetheenergy density of the devices. Transit fuel cell buses offer zero emissions and low noise operation, as well as greater fuel efficiency. Henceforth ,the proposed model spurs greens to rage and environment alfriendlytransportation. The power management unit shows the point of common coupling(PCC) where grid, load andinverter are coupled together with the co-ordination of two way/ PLCC based energy meter. There is a need to keep an eye on and safeguard the PCC. The direction of energy flow is decided depending upon the availability and demand of renewable energy ,energy storage and grid. Under the circumstances of grid failure, outage, blackout, power cut due to faults, if renewable energy inverter at that moment is active in any of the house then the utility operator or personal in some other house gets electric shock as utility is an infinite bus. This is called islanding, which refers to the condition in which a distributed (DG) generatorcontinuestopoweralocation even though electrical grid power from the electric utility is no longer present. Islanding can be dangerous to utility workers, who may not realize that a circuit is still powered, and it may prevent automatic re- connection of devices. For that reason, distributed generators must detect islanding and immediately stop producing power; this is referred to as anti-islanding. For this reason, solar inverters that are designed to supply power to the grid are generally required to have some sort of automatic anti-islanding circuitry in them. In intentional islanding, the generator disconnects from the grid, and forces the distributed generator to power the local circuit. This is often used as a power backup system for buildings that normally sell their excess power to the grid. Here ,it is preferred as it can isolate the PCC from the grid /utility and R.E inverter can power the selectedload.

The benefits of the proposed system are:

1. Minimum consumption of theenergy.
2. Minimum purchase from the utility resulting in cost saving of the user (low electricitybill).
3. Environment friendly compared to conventional backup powersystems.
4. Greenenergystorage:Nodisposalandlifetimeissues.
5. Encourages clean transportationsystem.
6. Better energy utilization due to smart energy management.

III. Pricing, Anticipation And Energy Utilisation

One of the key challenges in grid management is maintaining reliability. As demand and supply vary through out the day it seems to be a constraint in price forecasting. There are methods of storing energy from sun/wind/biomass which are used during mostly night timeincasesofpowerfailure.Howeverthesearenotthe wise and intelligent decision of utilisationof energyand do not consider future weather conditions, pricing, current storage capacity etc.. If the weather conditions varyunexpectedlyoveracertainregionfor aperiodthen on that aspects to ring energy be comesachallengingtask

.Itwouldberathermorecrucialifthegridfailsorpower cut occurs then the renewable energy cannot deliver any more energy and it would be a blackout situation. Therefore it should be preferable to store energy when the utility price is cheaper. When the utility price is cheaper to store energy, it is harassed from the utility as shown in the above Fig. throughthe power factor corrected(PFC) ac/dc rectifier and used during peak load demand.

Under light load (energy) demand and high renewable generation, there are two choices: 1)Selling the excess energy to utility 2) Storing the excessenergy.

Selling the surplus energy to utility may have some issues. Utility is strict about standards. The injected current into the utility should have low distortion and should follow standard norms. Utility may refuse to accept the conditioned power if not of standard power quality or may charge fine to the user.As penetration of distributed energy systems increases and the necessary technology is developed, it is anticipated that the distribution system will evolve to accommodate two- way power flows and will take full advantage of distributed energy resources. This evolution will take place first in new residential, business, and industrial developments, but for much of the grid, may not occur until existing distribution systems must be replaced due to age. The technology to dispatch residential and commercial loads, such as air conditioning and electric water heating, already exists and is being used during periods of peak demand.

The two way/PLCC meter/service panel for a building will be transformed into an intelligent electronic gateway. Advanced meters/service panels that enable electricity suppliers and customers to communicate in real time and optimize the performance and economics of the system will interact with smart inverters and controllers. The concept of power systems that generate and deliver direct current, such as PV/energy storage systems, may be revived to serve DC loads in energy efficient micro-grid infrastructures.. The harvested energy from the renewable energy sources is conditioned and used by the local load first without any support from the utility. If the energy output is higher than the instantaneous residential load demand, the surplus energy is: 1) stored or 2) sold to the utility if the storageisfull.Whenthedebitprice(rateatwhichutility sells energy) is low (during off peak hours), the energy from the utility is purchased to complete the storage if empty. During peak hours, debit price is higher. So, it should be tried to use utility energy at the least to keep the electricity bill low. Smart meter should provide the price values based on data sent by utility at a certain refreshing rate. In addition, it should measure the creditedanddebitedenergyinterms ofvaluesaswellas price.

In the proposed hybrid integrated system a pre-paid meter can also be unified. The energy required to be purchasedfromtheutilityisdonebyenteringtheenergy amount in the meter such a way that it gets deducted from the system and it results in low electricity bill which eventually highlights better energy management system. This is one of the application to a green data center.

IV. Power Electronicinterfaces

Power electronics is an essential component and plays a key role in making use of renewable energy. The generated energy from the renewable sources cannot be used as such in unregulated form. For the AC load the unregulated dc form should be converted into regulated ac form. Power electronics is a weak link as it reduces reliability and the power reaching at the point of coupling. Hence the power electronics becomes an essential interface. All of these interfacing technologies requirespecificpowerelectronicscapabilitiestoconvert the power generated into useful power that can be directly interconnected with the utility grid and/or can be used for consumer applications. Because of similar functions of these power electronics interfaces, the development of scalable, modular, low cost, highly reliable power electronic interfaces will improve the overall cost and durabilityofrenewableenergysystems.

The power electronics interface accepts power from the distributedenergysourceandconvertsittopowerat the requiredvoltageandfrequency.Forthestoragesystems, bidirectionalflowofpower between thestoragesandthe utility is required. For a power electronics interface four major modules are depicted. They include the source input converter module, an inverter module, the output interface module and the controller module. The design of the input converter module depends on the specific energy source or storage application. The DE systems thatgenerateACoutput,oftenwithvariablefrequencies, such as wind, micro turbine, IC engine, or flywheel storage needs an AC-DC converter. For DC output systems like PV, fuel cells, or batteries, a DC-DC converter is typically needed to change the DC voltage level. The DC-AC inverter module is the most generic of the modules and converts a DC source to grid- compatible AC power. The output interface module filters the AC output from the inverter and the monitoring and control module operates the interface, containing protection for the DE and utility point-of- common-coupling (PCC). The power electronic (PE) interface also contains some level of monitoring and controlfunctionality.

Benefits of power electronic devices include increased efficiency, lower cost, and reduced packaging size.

According to different source characteristics and specifications of PV, wind, and fuel cell, individual power converters are required to interface them to a common low voltage DC bus. This dc bus voltage is inverted by a single- phase inverter to utility interactive and load compatible ac power to feed the household or deliver power to the utility at nearly unity power factor. These individual power electronics systems are discussed as follows.

1. SOLARPHOTOVOLTAIC(PV)

Photovoltaic (PV) technology involves converting solarenergy directly into electricalenergy by meansofasolar cell.Asolarcellistypically madeofsemiconductormaterials such as crystalline silicon and absorbs sunlight and produces electricity through a process called the photovoltaic effect. The efficiency of a solar cell is determined by its ability to convert available un lightintousableelectricalenergyandis typically around 10%-15%. Therefore, to producesignificant amount of electrical energy, the solar cells must have large surfaceareas.

ForaPVsystem, thevoltageoutputisaconstantDC whose magnitude depends on the configuration in which the solar cells/modules are connected. On the other hand, the current output from the PV system primarily depends on the available solar irradiance. The main requirement of power electronic interfaces for the PV systems is to convert the generated DC voltage into a suitable AC for consumer use and utility connection. Generally, the DC voltage magnitude of the PV array is required to be boosted to a higher value by usingDC-DCconvertersbeforeconvertingthemtotheutility compatible AC. The DC-AC inverters are then utilized to convert the voltage to 60 Hz AC. The process of controlling the voltage and current output of the arraymust be optimized based on the weather conditions. Specialized control algorithms have been developed called maximum power point tracking (MPPT) to constantly extract the maximum amount of power from the array under varying conditions . The MPPT control process and the voltage boosting are usually implemented in the DC-DC converter, whereas the DC-AC inverter is used for grid-currentcontrol.

2. WINDENERGY

Wind turbines convert kinetic energy in the wind into mechanical power that can be converted into electrical energy with a generator. Power is normally generated either with an induction generator or with a synchronous generator. Synchronous generators are typically interconnected to the grid through power electronics. A brushless permanent magnet DC generator is connected to wind turbine for converting wind energy into electrical energy in DC form. A dc/dcconverterisrequiredfor thepower conditioning.Power outputistypically between10kWto2.5MWandwindpower is captured using a blade that is connected to the rotor of a generator.Thepowerisgeneratedonlywhenthewindblows. Like PV systems, there are no fuel costs, but periodic maintenance of the wind turbines is required. For better choice the converter used in pv may be used for specifications. A multi-port dc/dc converter with two input and single output can also be used. For higher power level, alternators with field windings arepreferred.

3. BIOMASSENERGY

BioPower—theuseoforganicmatterforpowerand fuel—offers a solution to the problem of excess biomass while also offering benefit ts in the form of environmentally sound, rural economic growth and national energy security benefit ts. Currently, 80% of the country’s energyis supplied by fossil fuels, which are finite and non-renewable. As a renewable energy source, Bio Power produces fewer emissions than conventional sources and canactually improve environmental quality by offsetting fossil fuel use and related emissions and by using wastes that are creating land use problems. Bio Power growth can also create new markets and employment for farmers and forest workers, many of whom currently face economic hardship. It can establish new processing, distribution, and service industries in rural communities.

Bio energy is the use of organic matter—such as wood, plants, residue from agriculture or forestry, and the organic component of municipal and industrial wastes—to provide heat, make fuels, and generate electricity. Wood, the largestsourceofbioenergy,hasbeen usedtoprovideheatfor thousands of years. In addition to heating, biomass can be used, like fossil fuels, to power automotive vehicles and generate electricity. Modern technology is working to improve the efficiency of bio energy production to increase its marketability. The two leading options for converting large amounts of biomass are conversion of biomass to electricity and conversion of biomass to liquidfuels.

Bio power plants operate in ways similar to most fossil-fuel fired power plants. The biomass fuel is burned in a boiler to produce high-pressure steam. This steam is introduced into a steam turbine, where it flows over a series of aerodynamic turbine blades, causing the turbine to rotate. The turbine is connected to an electric generator, so as the steam flow causes the turbine to rotate, the electric generator turns and electricity is produced. Biomass can be also beconverted directly into liquid fuels like ethanol and biodiesel for our transportation needs. Ethanol, an alcohol, is made by fermenting any biomass high in carbohydrates, like corn, through a process similar to brewing beer. It is mostly used as a fuel additive to cut down a vehicle's carbon monoxide and other smog-causing emissions. Biodiesel, an ester, is made using vegetable oils, animal fats, algae, or even recycled cooking greases. It can be used as a diesel additive to reduce vehicle emissions or in its pure form to fuel a vehicle.

4. FUELCELL

Fuel cells that are currently being developed can be used as possible substitutes for the internal combustion engine in vehicles as well as in stationary applications for power generation. A fuel cell is an electro-chemical device which produces electricity without any intermediate power conversion stage. The most significant advantages of fuel cells are low emission of green house gases and high power density. Fuel cells are similar to PV systems in that they produce DC power. Power conditioning systems, including inverters and DC-DC converters, are often required in order to supply normal customer load demand or send electricity into the grid. Fuel cell provides the continuous power in all seasons as long as the fuel supply is maintained. Fuel cells areassociated with lowvoltageandhighercurrent.Thiswide voltage variation with load current reduces the converter efficiency. Therefore, efficient power electronics needs to be design for optimal utilization. A current-fed system is preferred for fuel cell application. Current-fed half-bridge active-clamped dc/dc converter is selected for this application.

5. ENERGYSTORAGE

Energystoragetechnologiesareclassifiedaccording to the total energy, time, and transient response required for their operation. It is convenient to define storage capacity in terms of the time that the nominal energy capacity can cover the load at rated power. Storage capacity can be then categorized in terms of energy density requirements (for medium- and long-term needs) or in terms of power density requirements (for short and very short term needs). Energy storage enhances systems overall performance in three ways. First, it stabilizes and permits to run at a constant and stable output, despite load fluctuations. Second, it provides the ride through capability when there are dynamic variations of primary energy (such as those of sun, wind, and hydropower sources). Third, it permits to operate as a dispatch able unit. Moreover, energy storage can benefit power systems by damping peak surges in electricity demand, countering momentary power disturbances, providing outage ride- through while backup generators respond, and reserving energy for futuredemand.

Battery systems store electrical energy in the form of chemical energy. Many utility connections for batteries have a bidirectional charger/inverter, which allows energy to be stored and taken from the batteries. Super capacitors, also known as ultra capacitors, are electrical energy storage devices, which offer high-power density and extremely high- cycling capability. super capacitors are an interesting option for short-term high-power applications.

Flywheel systems have recently regained consideration as a viable means of supporting critical load during grid power interruption because of their fast response compared to electrochemical energy storage. Flywheel energy storage system (FESS) works on the principle that it stores energy in the form of the kinetic energy of a spinning mass. Conversion from kinetic to electric energy is accomplished by electromechanical machines. Many different types of generator machines are used in flywheel systems, such as permanent magnet machines, induction machines,andswitchedreluctancemachinesAdvancesinPE and digitally controlled fields have led to better flywheel designs that deliver a cost-effective alternative in the power quality market. Typically, an electric motor supplies mechanicalenergytotheflywheelandageneratoriscoupled on the same shaft that outputs the energy, when needed, though a PE converter. It is also possible to design a bidirectional PE system with one machine that is capable of motoring and regeneratingoperations.

6. AC to DCRectifier

Rectifier circuits are generally used to generate a controlled dc voltage from either an uncontrolled ac source (micro turbine and small PMG wind turbine) or the utility supply. When converting from a utility supply, a rectifier's application is usually for dc linking of systems or providing dc voltage for specific-load applications, such as battery regulators and variable frequency drive inputs. To improve theefficiency, boost and synchronous buck converterscanbe
used (.i.e. front-end diode bridge rectifier followed by boost converter followed by buck converter is sufficient).

7. DC TO DCCONVERTER

Converter circuits are almost always found in circuitsthatareusedforrenewableenergytobatterycharging applications.Theytakeanuncontrolled,unregulatedinputdc voltage depending on the specific load application. They are commonly found in PV battery charging systems. PV converter circuits are usually specialized units designed to extractthemaximumpoweroutputofthePVarray. Howeverinthiscaseamulti-portdc/ dcconverter with multiple outputs at different voltage level can be realized by multiple secondary windings of a high-frequencytransformer.

8. DC TO ACINVERTER

Invertercircuitsgeneratearegulatedacsupplyfrom a dc input. They are commonly found in systems providing stand-alone ac power & utility systems. To use the power available at the dc bus, a load/utility interactive dc/ac conversionisrequired.Theinverted power iseither fed tothe local residential load, injected into the utility. A high frequency inverter is required. Two types of controls are to be combined, i.e. voltage control in standalone mode and current control in grid-connected mode. low voltage is translated above peak of the utility ac voltage by a front-end dc/dc converter and then shaped into sinusoidal ac voltage of low total harmonic distortion (THD)asperstandards.Inmost cases high frequency transformer isolation ispreferred.

9. SENSOR & CONTROLNETWORK

The objective of integration of smart grid with renewableenergyistogetcontinuous&lowpriceelectricity. It provides energy storage & grid stability at grid side and supporting power to users at distribution side duringthe peak periods,whengridisoff,andwhendemandisaboveaverage. Renewable integration techniques have become quite maturedatthisstage.However,pricingandenergyeconomic policies, sensing, communication, intelligent computation and control in smart grid integrated with renewable have research opportunities and challenges. The proposal for a smart green building is asfollows:

1. Sensing and computation of:

A. Load demand at user'send
B. Price of the utilityenergy
C. Available energystorage
D. Possible renewableenergy

2. Communication and Control: Information available from step 1 is communicated to the data management point. Using the control network, following decisions arecommunicated:

1) Reduction in residentialload
2) Increasing load to utility line (if utility electricity price islow)
3) Reduce load to the utility line (if utility electricity price is higher) or completely isolating if usage is quitelow.
4) Allow use of storedenergy
5) Allowing renewable powerfor
(i) direct usageor
(ii) forstorage.
6) Consider storing if forecasting declaresbad weatherconditions.

Fast sensing, computation, communication and decision areneededtocompetewiththeswitchingfrequency of the power electronics system. To get low cost, compact and light weight power electronics, high switchingfrequency operation isneeded.

V. Conclusion

With the need to reduce the amount of greenhouse gases being spewed into the atmosphere globally, and to make more efficient use of expensive fossil fuels in energy efficient building design in our country is essential. Since small scale power systems are becoming popular & need for residential approach for developed

& underdeveloped countries utilization of smart energy management results in lower payback period. The proposed energy system allows reduction in electricity bill, secured & green storage, reduction of dependency on utilities, self supported peak demand during peak hours, continuity of power during grid failure, better energy utilization, reduced power quality concerns, enhanced energy saving & sustainable living. For long life span, maintenance & replacement issues energy storage is good to go for long years.

Present utility or grid system is such that it supplies full demand of a user as soon as it put on the system even if it is higher than the average demand. However, utility company may charge higher than usual rate. In future, with the increasing consumption of electricity by user, utility may not be able complete the user demandallthetime.Therefore, such integrated micro grid based energy system solves such concerns. Independent AC and DC grid to feed AC and DC loads respectively makes it suitable for residential power system as most of the residential load is DC. It is scalable to set-up a hybrid micro-grid for a residential township or commercial complexes.

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