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Current Stature and Future Outlook of Hybrid Renewable Energy System

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Abstract: Non renewable energy sources are the potential creators of global warming phenomenon, ozone layer depletion and emission of greenhouse gases thus creating doorway for renewable energy sources. But these renewable energy sources when considered alone do not prove to be efficient and hence in order to overcome the drawbacks of these systems hybrid power generating system with advancement in technology is being considered. This paper focuses on the use of fluidized bed and electrostatic precipitator in biomass energy system, singlet fission to generate solar power and sound isolating material in wind turbines and combining them altogether to generate power which is both efficient, reliable and environment friendly. Simulation and optimizing software are used for unit sizing and storage is done using battery which again is efficient and cost effective.

Keywords: Singlet fission, fluidized bed, electrostatic precipitator, simulation and optimizing software.

I. INTRODUCTION

The renewable energy system involves the use of renewable energy sources such as wind, solar, biomass etc for power generation. The drawbacks of these standalone non-conventional energy systems, which include low efficiency, high infrastructure cost, reliability of supply has necessitated the development of hybrid renewable energy system. The deployment of hybrid system for power generation has resulted in supply security, reduced emission of greenhouse gases, improved power quality and development in remoteareas [10]. Hybrid system on which this paper focuses considers solar, wind and biomass altogether to cater the growing energy demands and minimize the wastage of energy.

The high infrastructural cost and less efficiency of solar energy system, large area requirement and noise pollution from wind turbines and collapsing of biomass energy system at low temperature can be overcome by combining these systems together. The singlet fission can increase efficiency of solar power system; sound isolating material can reduce the noise generated from wind turbines and fluidized bed, gasification system and electrostatic precipitators prevent the collapsing of biomass system at low temperature. The advanced use of above mentioned technologies in hybrid energy system allows the system to run parallel and provide the continuous power supply and efficiency competitive to that of thermal power generation system.

II. EXISTING HYBRID RENEWABLE ENERGY SYSTEM

A. Photovoltaic–Wind Renewable Energy System

Solar Wind hybrids use solar panel and small wind turbine generators to generate electricity. They work in small capacities. Typical capacities are in the range of *1KW* to *10KW* for this hybrid system. Researches have already been made to extensive heights in order to obtain maximum output from this system in the field of its efficiency and cost effectiveness. In commercial and industrial sectors the systems are used in rural offices or small tourist hotels where power shortage is chronic. It can be used in schools especially in rural and urban fringe areas. It can be used for military (charging of communication units) as well as in railways (track signalling).The solar panel and wind turbine work in tandem to charge a battery via a controller. The wind turbine configuration could be a vertical axis or a horizontal axis.

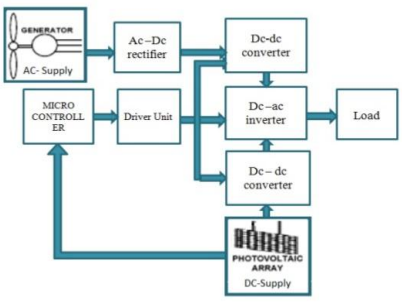

Fig.1: Block diagram Hybrid Wind-Solar energy system.

The smaller system 1KW takes up about $1m^2$ of area for wind turbine and typically $12m^2$ for solar panels. The possibility of supplying electricity to a remote village in Ethiopia through the PV-Wind energy system along with supplementary diesel engine was investigated by Bekele and Palm. Size optimization of the hybrid system is firstly done through simulations in turkey.

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B. PV-Biomass Power System

This system consists of photovoltaic array integrated with a biomass generator. The components of this system include a biomass generator, a charge controller, a battery bank for storage, PV array and a DC/AC converter. It is considered as the better option to solve the electrification problem in remote areas where extension of power grid proves to be costly and unmanageable. When it comes to design and sizing of the system the system is considered as autonomous thus providing infinite number of possible system configurations.

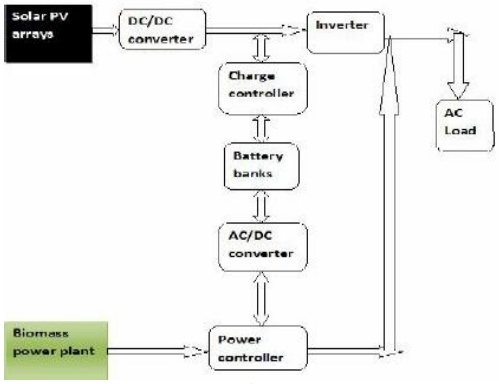

Fig 2: Block diagram of photovoltaic-wind power system

The seven demonstration hybrid renewable energy projects that have been conducted to meet the overpowering electrical demands have been discussed below along with the key technology used in each power plant.

- Utsira Island, Norway: This hybrid system supplies energy to the residents of the island. It makes use of flywheel and battery to store the power generated from this wind and hydrogen fuel cell hybrid system.[1]
- Kahua Ranch, Hawaii Hydrogen Power Park, USA: The power so developed using hydrogen generated from wind-PV-Electrolyzer-FC energy system is used to supply energy to Kahua ranch.[3]
- Starkenburger Lodge, Austria: This plant meets the energy demand of a lodge in remote area of Austrian Alps. It is a completely off grid system which uses photovoltaic method of storage.[4]
- Fuel cells and Energy Networks of Electricity, heat, and hydrogen, Japan (Project NEXT 21):More than 5000 PEMFCs (fuelled by natural gas) were installed in residential households on an experimental basis by the end of 2009. The PEMFC units provide electricity and hot water to the households.[7].
- The Kythnos Island microgrid project, Greece: The system in Gaidouromantra, Kythnos is a 1-phase micro grid composed of the overhead power lines and a communication cable running in parallel. It is electrifying few houses in a small valley in Kythnos [8].
- The Hachinohe micro grid project, Japan: The purpose of this Renewable-Energy-Based micro grid, built in the urban city of Hachinohe, is to investigate its grid integration and stabilization, as well as control and reliable operation in islanded mode.[8]

Wind2H2 Project, National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory (NREL), USA: The Wind2H2 system was initially approved for demonstration operation in March 2007. The system produces hydrogen directly from RE sources through electrolyzers. The generated hydrogen is stored in high pressure storage tanks and can be used both as a transportation fuel and as an energy storage medium [5], [6].

III. SOLAR/BIOMASS/WIND/HYBRID RENEWABLE ENERGY SYSTEM

Most of us already know how a solar, wind and biomass power generating system works. All these generating systems have some or the other drawbacks. The combination of these three systems has proved to overcome the associated drawbacks to a great extent.

A. Solar Power System

The array of photovoltaic power system produces direct current power which fluctuates with the sunlight's intensity. Through the use of inverter we can obtain desired voltage and alternating current.

Similar to transistor material, solar cell are made up of semiconducting material like Silicon (Si), Gallium Arsenide (*GaAs*), Copper Indium Gallium di-Selenide ($CuInSe_2$), Cadmium Telluride (*CdTe*) and amorphous Silicon. The solar cells which are mostly used in present scenario uses the materials which include mono crystalline Silicon, polycrystalline Silicon, amorphous Silicon, and Cadmium Telluride and Copper Indium Selenide.

The amount of current generated by a PV cell depends on its efficiency, size and intensity of sunlight striking on the surface.

The efficiency of PV system by using above mentioned material is limited to only 10% for Si, *12%* for $CuInSe_2$ and *9%* for *CdTe*. The highest efficiency recorded is as high as *43.5%* for multiple junction cells.

The current status of solar power systems calls for the need of development of such a system that increases its efficiency to a far more extent. Hence four chemists at the University of California Riverside (UCR) have broken a long standing barrier on energy conversion efficiency in PV cell. They proposed a system called singlet fission by which a single exciton splits into two triplet exciton for increment in efficiency up to *30%*. [14]

The current photovoltaic cells are unable to surpass the efficiency barrier over *33%* due to the Shockley-Queisser limit. A boost of *30%*, to a total efficiency of *60%* or more would be absolutely huge and exactly what solar power needs.

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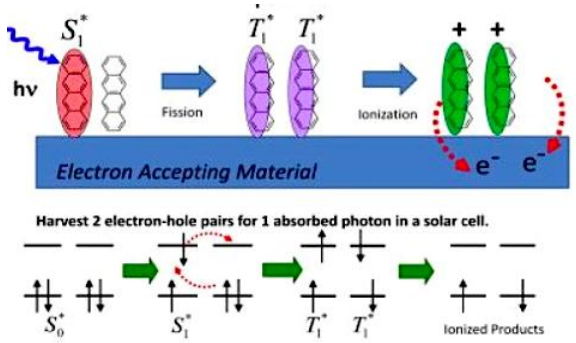

Fig. 3. Diagram showing singlet fission i.e. two excitons generate by one photon.

The most important step in this system is choosing of material with the right energy level. For fission to occur spontaneously and rapidly, the energy level of original exciton should be more than twice the energy level of two new excitons. Singlet fission affects only the high energy photons, moreover to get out twice as many electrons they have to halve the energy per electron and that further halve the voltage that the solar cell puts out.

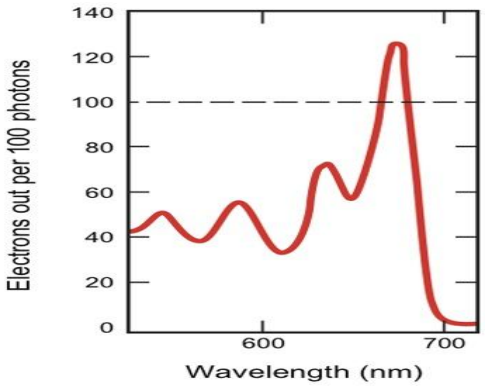

Fig. 4. Graph showing number of electrons ejection for every 100 photons at different wavelength.

Figure(4) Shows on left side at some wavelengths, the device generate more electrons than can be extracted from a conventional solar cell. Maximum production occurs at the wavelength of 670 nm, when 126 electrons come out for every 100 photons go

B. Biomass Energy System

Biomass is used for facility heating, electric power generation and combined heat and power. The term biomass encompasses a large variety of material including wood from various sources, agricultural residue, and animal and human waste.

Biomass can be converted into electric power by several methods such as direct combustion, pyrolysis and anaerobic digestion. The drawback of biomass is that the fuel needs to be procured, delivered and stored. Also biomass combustion produces emissions which must be carefully monitored. The control of emission for unburned hydrocarbons, oxides of nitrogen and sulphur can be done by using electrostatic precipitators. Drying the biomass before combusting or gasifying it improves the overall efficiency.

Fluidized bed system:-It houses two systems, circulating fluidized-bed and bubbling fluidized bed in which the biomass is burned in a hot bed of suspended, incombustible particles, such as sand. It produces more complete carbon conversion resulting in reduced emission and hence improved system efficiency.

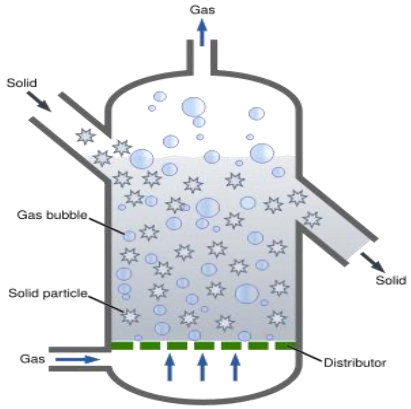

Fig.5.Basic Fluidized Bed

The system proves to be efficient CO_2, Sulphur and Nitrous Oxide removal because of the high temperature and pressure of the produced syngas. Captured gases are prevented from entering the atmosphere through either utilization or storage. Gassifiers can also handle pet coke and other refinery products. Syngas produced by gasification can also be further processed into liquid fuels.
Electrostatic precipitators: It is a technique used to decrease the pollution contents in the fuel gases. It is generally used in thermal power plants to control the pollution caused due to generation of greenhouse gases. This system is extensively used in removal of fly ash from electric utility boiler emission.

It can be designed to run at any desired efficiency. The running charge of the system is high. However, in spite of this it is frequently used for its effectiveness on fly ash particles with other type of collector. It consists of discharge wire and collecting plates. A high voltage is applied to the discharge wire to form an electric field between the wires and collecting plates, and also ionizes the gas around the discharge wires to supply ions. Smoke particles are attracted to the collecting plates which are earth or positively charged and then removed by collecting plates which then fall into a collector. The metal grids in the electrostatic precipitators are given a high voltage.
The important factor when planning this system is the electrical resistivity of dust to be collected.

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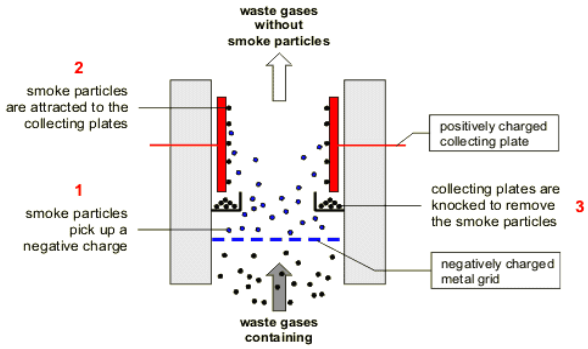

Fig. 6. System showing the working of Electrostatic Precipitator

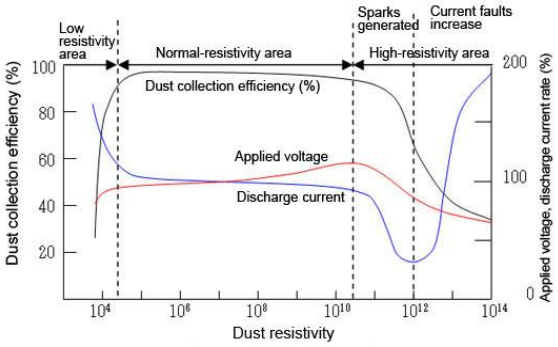

Fig. 7. Defining resistivity area in terms of dust collection efficiency

Figure (7) shows that in the normal resistivity area efficiency is high but in low resistivity area efficiency is greatly reduced. The same can be witnessed in high resistivity area.

C. Wind Power System

Wind turbines are important in creation of energy because of its tremendous speed, effectiveness of cost and eco-friendly nature. However the available wind energy cannot be captured effectively because of variability of wind. The main focus thereby lies within describing ways to capture maximum amount of wind energy. Techniques have been developed in the direction of improving efficiency by adjusting rapidly changing wind conditions which aims to constantly monitor the forces exerted on wind turbine blades through sensors and computational software. The changes are being introduced in the wind turbine structure.

The information from the sensors is fed into the active control system that adjusts components to optimize efficiency and helps to improve the reliability by providing real time information to prevent the catastrophic wind turbine damage. The sensors that are embedded into the system have control surfaces and simple flaps that aim at changing the aerodynamics characteristics of the blade. It helps in estimating force exerted on the blades because of dynamic and static acceleration. The sound isolating material used in the system helped to avoid the noise

IV. SYSTEM DESIGN

A hybrid power plant consisting of these four alternative cleaner energy sources (solar, wind, biomass and hydrogen) with some effective technologies can be taken into operation by proper utilization of these resources in a completely controlled manner.

- After checking the demand and supply in the rural and urban areas the excess energy can be used as the product ion of hydrogen and stored to meet the demands.
- In winter season when solar cell does not function, hydrogen generated from the biomass generator can help to maintain the continuity of supply and also prevents the system from collapsing.

Factors that are needed to be considered for modelling of hybrid entity:

A. *Power Reliability Analysis*

Power reliability plays a vital role in the designing of hybrid system in a way that is both economical and efficient. Various methods have been used to estimate the reliability of the hybrid system, loss of power, supply probability, loss of load probability [19, 20], system performance level and loss of load hours [22]. The load demand is pre-determined with the help of substantial improvements in technology. Because of fluctuating nature of solar and wind energy arising due to varying atmospheric conditions the exact estimation of power reliability is best suited.

B. *System Cost Model*

To check the affordability of the proposed system cost analysis become mandatory. Determination of unit price of power is done using various methods which houses net present cost, annualized cost, half cycle cost [24] and levelised cost of energy [23]. The wind-solar-biomass collaborative system has been proposed earlier but for the system to be economically feasible and realistic technological advancement in unit sizing optimization is required.

V. UNIT SIZING

It is very well known that solar and wind power stations requires tremendous coverage area and when they are to work as a single unit definitely the area required will be more. Estimating the size of the system becomes very essential in order to reduce the over sizing of the components and minimization o system cost. The load demand is essential to be pre-determined for estimating the size of system components and this is carried out using optimization tools.

The software industry has provided solution to the very problem of unit sizing optimization through various methods among which simulation has achieved remarkable progress. The software which is designed to resolve the problem include, HYBRID, HOGA, HOMER etc. The software which is being used in estimating the size of proposed system is HOMER. On the basis of environmental data and simulation it performs

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optimization based on net present cost and the data can be used relevantly.

VI. STORAGE

To supply the energy to the load the important and critical task is to choose a better storage technology. Numerous storage techniques can be used in the hybrid non-conventional energy system like compressed air energy storage, pumped hydro storage, hydrogen fuel cells, flywheels and so on but there are certain parameters that should be kept in mind while choosing storage technology: efficiency, maturity of technology, cost energy density and power density. Among all the above mentioned technologies battery storage is given higher preference because of low cost, high efficiency. But hydrogen fuel cell is more suited in our system because the excess energy generated can be used in the production of hydrogen which helps in overpowering the drawback of continuous energy supply by foiling the wastage of energy.

VII. FUTURE TRENDS AND LIMITATIONS

The enormous researches have already been carried out but there are still certain obstacles which are needed to be crossed over. They comprise:

- Can the miscegenation system work with same efficiency if the load demand is increased?
- The parallel operation of all the three power system should have the same effectiveness even in off grid paradigm.
- The efficiency of solar power system need to be increased over *60%*.
- The size of the system need to as such so that it can be constructed in nearly all possible terrains.

VIII. CONCLUSION

This paper gives an overview of hybrid renewable energy system. The use of optimization and simulation is done to generate a system which meets the rising energy demand. The attempt is made to increase the efficiency of the individual non-conventional energy sources to an extent so that their high infrastructural cost may not prove to be a matter of concern.

Combining biomass with solar and wind provided a system that ensured continuity of supply. The future scope of the system is needed to be given greater importance thus minimizing every possible limit and preparing a system which can give equal efficiency competence to thermal power systems.

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