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An Analysis and Review on Solar-Biomass Hybrid System

Sachchidanand Pandey[1] Dr. Devendra Vashist[2]

[1]Research Scholar, Manav Rachna International University

[2]Professor, Manav Rachna International University

Abstract – Renewable energy technologies are suitable for off-grid services, serving the remote areas without having to build or extend expensive and complicated grid infrastructure. Therefore hybrid systems using renewable energy sources have become a preferred option. India has good potential of solar and biomass resources. A review of various technologies of solar biomass hybrid systems is made. Findings indicates that hybrid solar biomass power plants will become an increasingly attractive option as steam energy storage methods improve, solar thermal costs decrease and biomass feedstock and fossil fuel prices rise. More focus should be given to making technological improvements to the heat cycle of small scale hybrid plants due to low energy and energetic efficiencies. Hybrid Systems have proved to be the best option to deliver "high quality" community energy services to rural areas at the lowest economic cost, and with maximum social and environmental benefits.

Keywords: Concentrating Solar Power (CSP), Biomass, Hybrid Renewable Energy Systems (HRES), Hybrid Power Systems.

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INTRODUCTION

Rapid depletion of fossil fuels has necessitated an urgent need for alternative sources of energy to cater the continuously increasing energy demand. Another key reason to reduce our consumption of fossil fuels is the growing global warming phenomena. Environmentally friendly power generation technologies will play an important role in future power supply. The renewable energy (RE) technologies include power generation from renewable energy sources, such as wind, PV (photovoltaic), MH (micro hydro), biomass, ocean wave, geothermal and tides. In general, the key reason for the deployment of the above energy systems are their benefits, such as supply security, reduced carbon emission, improved power quality, reliability and employment opportunity to the local people. Since the RE resources are intermittent in nature therefore, hybrid combinations of two or more power generation technologies, along with storage can improve system performance.

The potential for biomass boilers in India is vast with over 370 million tons of biomass being produced every year [1]. Biomass is available from agricultural wastes, direct harvesting and as a by-product from industries such as rice mills, sugar mills and saw mills. However, due to problems with infrastructure and the seasonal variability of biomass in India, consumers are struggling to obtain a consistent fuel supply. Furthermore, while biomass is still competitive, prices have increased considerably in recent years. The solar energy is an intermittent nature of source. Integration of single source plants like combined cycle plants improve the overall energy conversion efficiency but it would not address the scarcity of fuel especially for seasonal available fuels. Similarly the maximum limit for performance of solar thermal based power plant also limited to some extent. Hybridization of solar thermal with biomass combustion complements each other, both seasonally and diurnally, to overcome their individual drawbacks and results continuous and uniform supply. The sun's rays can be harnessed by solar collectors and biomass feedstock can be burnt as a supplementary fuel to achieve constant base load operation. Reviews shows Hybrid power system has a great future due to its more flexibility in operation [2]. Research and development efforts in solar, wind, and other renewable energy technologies are required to continue for, improving their performance, establishing techniques for accurately predicting their output and reliably integrating them with other conventional generating sources. Hybrid power systems can also be designed for power, heat and hydrogen generation [2]. Hybrid plants will become an increasingly attractive option as the cost of solar thermal falls and feedstock, fossil fuel and land prices continue to rise [2]. Numerous hurdles are to be overcome by conventional energy plants, for electricity production. Hybrid systems can be

replicated at many different scales, thus enhancing the transition from a centralized production distribution scheme to a more distributed model, such as interlinked microgrids, for which renewable energies have been pointed to as an efficient solution. The use of such energy sources would improve the development of rural areas, creating job opportunities, as well as revaluating local resources not currently used. In this paper the two sources of energy i.e biomass and solar are extensively discussed. Further findings of the researches that are in progress using the combined system of solar and biomass are thoroughly analyzed. Analysis indicate that biomass based hybrid systems are environmental friendly and sustainable. Biomass combustion is a mature technology with a large number of power plants in operation worldwide. However, the energy efficiency of this technology is limited and the operating and investment costs are high, resulting in low financial returns. Apart from providing energy to rural communities, hybrid renewable energy systems (HRES) can also provide employment opportunity for rural people.

BIOMASS

Biomass is a renewable energy resource derived from tire carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood. It is a biological material derived from living, or recently living organisms. It may often refers to plants or plant-based materials which are specifically called lignocellulasic biomass. [3] As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly alter converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemical methods. Wood remains live largest biomass energy source to date: examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. In live second sense, biomass includes plant or animal matter that can be convened into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switehgrass. hemp, willow, sorghum, sugarcane, bamboo, and a variety of other species, ranging from eucalyptus to palm oil. [3] Biomass can be convened to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel.

SOLAR POWER

In Concentrating Solar Power (CSP) plants, electricity is generated by heating a fluid (synthetic oil) to high temperatures (typically over 375ºC) using solar radiation that has been concentrated using mirrors or lenses. The hot fluid is used to produce superheated steam (370-375 ºC, 90-100 bar depending on the characteristics of the Rankine cycle) [4] that drives a Rankine cycle steam turbine connected to an electricity generator. Different technologies have been developed to concentrate the solar radiation, depending on the required fluid temperature, plant size and capacity. The most widely used are power towers and parabolic throughs. A key drawback in CSP plants relates to the intermittence of its power generation, due to the day / night cycles and also the periods of reduced irradiation (winter, cloudy periods). To overcome this problem, research is being conducted to develop efficient heat storage systems (molten salts, concrete, latent heat) and other energy storage alternatives (pumped hydroelectricity, hydrogen, etc). [5] However, these technologies have been reported to be expensive [5] and / or not sufficiently proven.

HYBRID RENEWABLE ENERGY SYSTEMS

Hybrid renewable energy systems (HRES) are recognized as effective means to locally exploit renewable energies for electricity and, in certain cases, heat-production. These systems combine two or more energy sources, one of them being a renewable energy source, usually combining sources that can counteract the weaknesses of the others. An important reason for the interest attracted recently by HRESs is their remarkable ability to foster the deployment of renewable energies, currently the better alternative for CO_2 emissions reduction. HRES optimization is a research field with great areas to be explored, such as the creation of new methodologies that could help to inform decision makers in the design stages of projects. These methodologies can provide support tools for system sizing or evaluation of trade-offs among different alternatives due to their ability to tackle non-linear problems with relatively high calculation speeds.

HYBRID POWER SYSTEM

Hybrid power systems use local renewable resources to provide power. Community hybrid power systems can range in size from small household systems (100 Wh/day) to systems supplying a whole area (10's MWh/day). [6] They combine many technologies to provide reliable power that is tailored to the local resources and community. Off grid renewable energy technologies satisfy energy demand directly and avoid the need for long distribution infrastructures. A combination of different but complementary energy generation systems based on renewable energies or mixed (with a backup of Liquefied Petroleum Gas (LPG) / diesel / gasoline genset), is known as a hybrid power system or hybrid system [7] Hybrid systems capture the best features of each energy resource and can provide "grid-quality" electricity, with a power range between 1 kilowatt (kW) to several hundred kilowatts. They can be developed as new integrated designs within small electricity distribution systems (mini-grids) and can also be retrofitted in diesel based power systems. They are generally independent of large centralized electric grids and are used in remote

areas. In these systems it is possible for the individual power sources to provide different percentages of the total load. For instance, on a cloudy windy day when the solar panels are producing low levels of electricity, the wind generator compensates by producing a lot of electricity.

HYBRID POWER SYSTEM DESIGN

Hybrid Power Systems incorporate several electricity generating components with usually one major control system which enables the system to supply electricity in the required quality. A typical hybrid system combines two or more energy sources, from renewable energy technologies, such as photovoltaic panels, wind or small hydro turbines; and from conventional technologies, usually diesel or LPG gensets (though biomass fed gensets are also a feasible option, if locally available). In addition, it includes power electronics and electricity storage batteries. The hybrid system can be designed in different configurations to effectively use the locally available renewable energy sources and to serve all power appliances (requiring DC or AC electricity). The technological configurations can be classified according to the voltage they are coupled with; for example, using DC, AC and mixed (DC and AC) bus lines. Hybrid systems with a backup genset run with minimal fuel consumption because the genset is brought on line only to assist in periods of high loads or low renewable power availability. This results in a large reduction in fuel consumption as compared to the system which is powered by only genset. Advance research on automation and control of hybrid power system made it popular to the world and encourage researchers to use different kind of renewable sources to reduce the demand of conventional energy sources. Figure 1 shows technological configuration of hybrid power system.

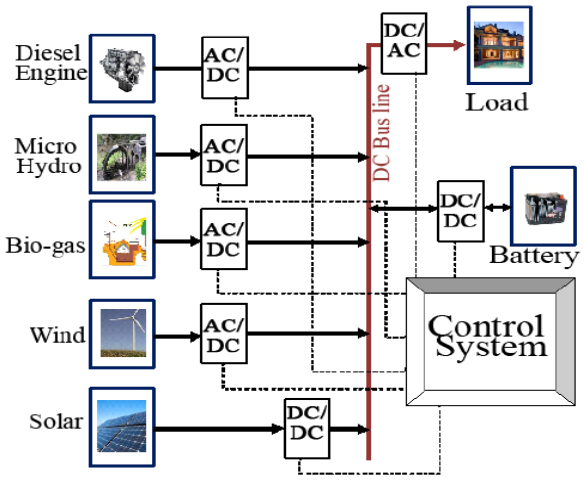

Figure1. Technological Configuration of Hybrid Power System

Among the non-conventional energy sources solar and wind are weather dependent while Bio-gas and Micro Hydro are weather independent.

SOLAR THERMAL BIOMASS HYBRID SYSTEM

A schematic layout for the hybrid solar thermal biomass power plant is shown in figure 2.

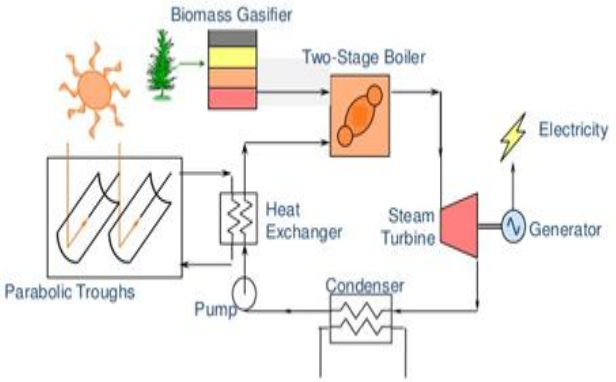

Figure 2 Simple layout of hybrid solar thermal biomass plant

Another schematic layout for the hybrid power plant with water / steam, air and gas circuits is shown in figure 3. It is operated on a simple regenerative steam i.e Rankine cycle. The heat source is separated and arranged in parallel for solar and biomass systems. The steam is generated from two sources in day time. In night time, steam can be generated only from biomass energy source without stopping. Biomass and preheated air are supplied to combustion chamber for complete combustion. The hot flue gases coming from the furnace flows over water / steam coils to generate steam from the feed water. The heat exchangers in the direction of flue gas are superheater (SH), evaporator, economizer, condensate preheater (CPH) and air preheater (APH) and arranged to match the temperature glide. The biomass power plant is designed to operate from half load to full load condition. The condition of equal sharing occurs in day time at maximum available solar radiation in solar noon time. The full load condition for biomass plant will be reached in the night, sunrise and sunset timings. The biomass power plant will be operated at part load conditions from 50% to 100% load capacity between sunrise to noon and noon to sunset. An open feed water heater known as deaerator is located in between condenser pressure and boiler pressure. It is an inevitable component in a steam power plant, Its location is defined in temperature ratio to analyze the deaerator pressure or temperature. The collector's efficiency decreases with an increase in working fluid temperature. Therefore, the steam temperature from

collectors is limited to 350 °C to control the heat losses.

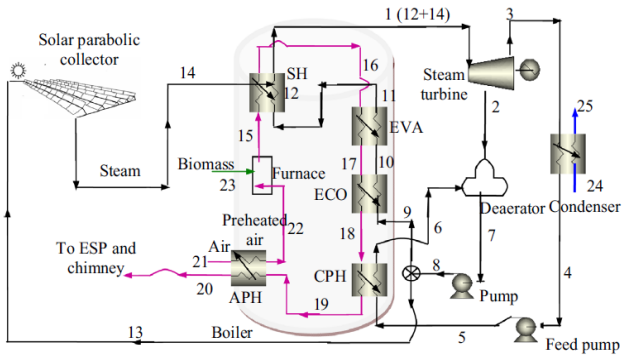

Fig.3.Hybrid solar–biomass power plant with solar collector sand biomass combustor.

LITERATURE FINDINGS

Perez-Navarro et al.[8] proposed a hybrid system, combining a biomass gasification and a wind generation plants. This hybrid system can mitigate wind prediction errors and so provide a predictable source of electricity. Astolfi et al. [9] evaluated the potential of a hybrid solar–geothermal plant based on an organic eRankine cycle (ORC). On the basis of current cost of solar, levelized cost of electricity of 145-280 €/MWh were obtained depending upon the location of the plant. Nixon et al.[10] compared to biomass only, hybrid operation and showed a 29% of biomass savings. Michael Hart et al.[11] studied about the hybrid biomass–solar thermal system for heating and domestic hot water preparation for small residential applications. J.Servert et al [12] in their studies concluded that investment costs for hybrid Concentrating Solar Power (CSP) - biomass power plants are higher than for conventional CSP and biomass combustion plants alone. However, owing to the shared use of some of the equipment, this value is significantly lower (24% saving) than a simple addition of the investment costs associated with the two standard technologies. Kumaravel S etal [13] conducted techno-economic study of biomass based hybrid renewable energy systems for the microgrid application operated in rural area. They concluded that the grid connected hybrid system requires additional capital cost of 8.79% but the cost of energy obtained through this system is 3.61 per kWh. Nixon J D et.al [10] in their study of hybrid solar – biomass power plant concluded that in comparison to biomass-only, hybrid operation saves up to 29% biomass and land. They further concluded that hybrid plants will become an increasingly attractive option as the cost of solar thermal falls and feedstock, fossil fuel and land prices continue to rise. There are two main areas of research in hybridization option direct thermal transfer and indirect thermal transfer [14]. Thermal conversion of biomass materials to higher calorific value and dense fuels is currently gaining increased international interest due to their renewable character and potential to reduce greenhouse gas emissions [15]. Biomass gasification and pyrolysis plants typically require external electrical power for operation when the plants are optimized for fuel production [14]. Janani Chakravarthi [16] examined a working model of biogas plant for its economic value as an alternative energy source. He further concluded that methanol obtained from methane of biomass (cattle waste) is an excellent fuel for IC Engines. Treating animal waste with the technology of anaerobic digestion can reduce environmental pollution and generate relatively cheap and readily available source of energy in dairy farms. Gianni Celli. Et.al [17] presented in their paper about Optimal Location of Biogas and Biomass generation plants. In this paper they presented the use of optimization algorithm for biomass availability, transportation, power facilities along with territory related constraints. They finally concluded that integration of optimization tools within Geographic Information Systems allows better performances of the unit. Combined heat and power production with biomass can help improve the energy efficiency of agricultural industries, and increase environmental sustainability of food. Zhang Yanning, Kang Longyim, (2009) [18] in his paper studied biogas generation and working process of Gas Engine. Kavali Janardhan et. al [19] evaluated the technical, economic and CO2 mitigation potential of solar PV-bio hybrid system. C. M. Iftekhar Hussain et.al [20] explore different solar technologies and its suitability for hybridization with biomass for combined heat and power (CHP) generation in Europe.

DISCUSSION

For small-mid scale applications (2-10 MW thermal), hybrid solar-biomass power plants are currently a feasible option for tri-generation (electricity, cooling and heat) in India, providing solar capital subsidies remain in place (30% grid-connected, 60% off-grid). Industrial process heat also presents a viable option for applications with an effective utilisation of heat. At these scales there are better options for generating electricity only. However, hybrid solar biomass power plants will become an increasingly attractive option as steam energy storage methods improve, solar thermal costs decrease and biomass feedstock and fossil fuel prices rise. Focus should be given to making technological improvements to the heat cycle of small scale hybrid plants due to low energy and exergetic efficiencies. While biomass-only systems are currently more economically viable, for a small independent rural area where supply of bimass as feedstock is plenty. Hybrid plants should be up-scaled in India for electricity generation, this would aid in keeping solar thermal a competitive option in comparison to alternative renewable energy technologies and can establish India as a global leader on hybrid solar-biomass power systems.

CONCLUSION

From the literature review it is concluded that

i. Biomass based hybrid systems are environmental friendly and sustainable.

ii. Two types of alternative sources were studied i.e Biomass and Solar.

iii. The technology behind power generation from hybrid system ie Biomass and Solar was studied and was found to be simple and reliable when used systematically.

iv. Using solar energy to provide the heat for thermochemical biomass processing would reduce the environmental impact of both gasification and pyrolysis.

v. Biomass combustion is a mature technology with a large number of power plants in operation worldwide. However, the energy efficiency of this technology is limited and the operating and investment costs are high, resulting in low financial returns.

vi. Apart from providing energy to rural communities, HRES can also provide employment opportunity for rural people.

vii. Hybrid Systems have proved to be the best option to deliver "high quality" community energy services to rural areas at the lowest economic cost, and with maximum social and environmental benefits.

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