Proposal for a Biomass Supported Solar Power Plant

Bhavika Rathore[1] Monika Vardia[2] Dr. P. C. Bapna[3]
[1]Student [2]Associate Professor [3]Professor & Head
[1,2,3]Department of Electrical Engineering
[1,2,3]Geetanjali Institute of Technical Studies, Udaipur

Abstract— Environmental, economic and strategic reasons are behind the rapid impulse in the deployment of alternative or renewable energy sources that are taking place around the world. Further, the growing scarcity and rising prices of fossil fuels may also lead to economical instability in the future. These problems can be solved by the use of renewable energy resources, which have the capability to meet the world's energy requirement. Thus sustainable and renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, biomass energy and tidal power are the need of the modern world. Solar and biomass are the alone renewable assets that accomplish a most of the locations of India. The use of solar radiation and biomass for power generation is growing rapidly, particularly in areas of the globe where these resources are plentiful. However, solar energy plants necessarily suffer from the intermittency and also from reduced irradiation periods particularly in winters and cloudy days. Biomass power plants have to confront the logistic problems associated with the continuous supply of very large amounts of a relatively scarce and seasonal fuel. Biomass alone access works but accumulation can be an issue, particularly in drought conditions results in variable operating and maintenance cost. To overcome the disadvantages of both of these plants, a hybrid system may provide the solution in maximizing the energy potential of these resources, increasing process efficiency, providing greater security of supply and reducing overall costs. This paper presents an introduction to the production of electricity from conventional concentrating solar power and biomass power plants, which is used as the basis to evaluate the technical and economic benefits associated with hybrid CSP-biomass energy systems. The generation technology and the operational characteristics are also presented in this paper. This paper outlines the most important configuration of this hybrid system along with the major problems and suitable solutions associated with this system have been also highlighted in this paper.

Key words: Renewable energy, Concentrating solar power, Biomass energy, Hybrid technologies, Different configuration and operational characteristics

I. INTRODUCTION

Most governments in the world are adopting measures aimed at facilitating the deployment of renewable energy sources. In concentrating solar power (CSP) plants, electricity is generated by heating a fluid at 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 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 [1]. The most widely used are power towers and parabolic through. 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 particularly in winter and cloudy periods.

In contrast, biomass is accessible from agricultural wastes, direct harvest from home and as a by-product from industries like rice mills, sugar mills and saw mills. Biomass combustion is a mature technology with a large number of power plants in operation worldwide. However, as a result of issues with infrastructure and seasonal variability of biomass in India, there is a troubled to get a homogenous fuel. Moreover, whereas biomass continues to be competitive, costs have raised significantly in recent years [2].

Hybridization of solar thermal with biomass power plant combines two energy sources that complement each other, to beat the individual drawbacks [3] that exist in both the plants. Throughout the day the solar energy may be controlled by solar collectors and biomass feedstock may be burnt as a supplementary fuel to realize constant base load operation.

II. CHARACTERISTICS OF BIOMASS SUPPORTED SOLAR POWER PLANT

In solar power plant solar collectors are used to collect thermal energy from ultra-violet rays of sun. In the obtained energy is insufficient to meet the load demand then the stored energy or a biomass power plant is used. Hence constant electrical output is obtained. The problem associated with the stored energy is that it may deplete sooner and no more energy remains to supply the extra load demand. But the storage energy of biomass supported solar power plant remains almost constant throughout the day. Therefore the electrical energy produced is stable and continuous [4]. The energy versus time characteristics of a hybrid solar thermal biomass power plant is shown in fig.1.

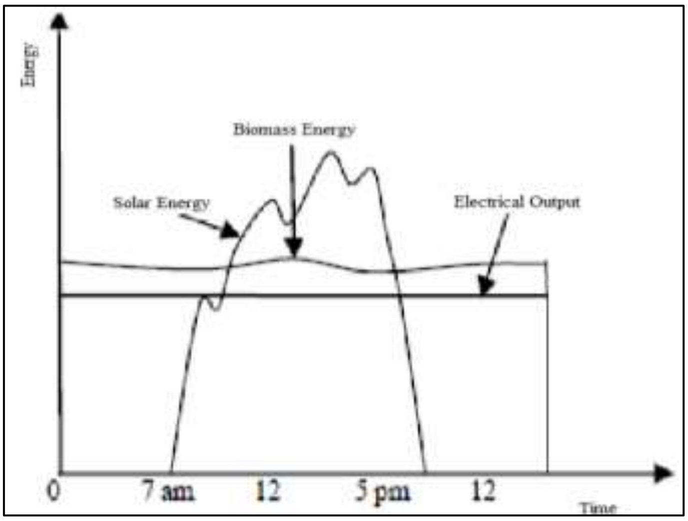

Fig. 1: Characteristics of biomass supported solar power plant

III. TECHNICAL ASSESSMENT OF CSP AND BIOMASS COMBUSTION

Both CSP and biomass combustion plants are based on the Rankine cycle where thermal energy is used to generate superheated steam and obtain electricity using a turbine-generator set. In this section the main elements used in conventional CSP and biomass power station and the different specifications are described.

A. CSP plants

In CSP plants, moving mirrors track the sun in order to concentrate the solar radiation onto the heating fluid. Different designs have been developed, the most common being parabolic troughs. The energy contained in the heat transfer fluid (HTF) is transferred to a water feed to generate superheated steam in a multiple stage heat exchange system. This steam is directed onto a turbine generator set. [1]

1) The most important elements in CSP plants are:
2) The solar collectors are made up of a supporting structure, mirrors (where the solar beams are reflected and directed to the absorber tube), absorber tubes (containing the HTF), and the tracking systems. The solar system is usually backed up by a natural gas boiler that operates at different rates depending on the degree of solar irradiation.
3) The heat recovery boiler is where heat from the HTF is used to generate superheated steam (370-375ºC, 90-100 bar). Most heat recovery boilers consist of several heat exchange stages, including an economizer, an evaporator and a superheater. Depending on the type of plant and cycle optimization, a reheater may be also included.
4) Auxiliary equipment like pumps is used in the plant which is specially designed to operate with HTF. Variable frequency drives (VFD) are used to control the pumping force that is exerted at every moment, in order to adjust HTF flows to the plant requirements. To keep production during cloudy weather and facilitate the operation and starting off of the solar field at low temperatures, natural gas boilers are used to ensure optimum temperature of the transfer fluid.

B. Biomass combustion plant

The main component in this system is boiler, in which biomass is burnt to generate superheated steam. Energy generated in the combustion process is used to heat the feed water (economizer), generate steam (evaporator) and superheat the steam to its final temperature and pressure (superheater). All the components regarding biomass storage and preparation area need to be considered in a technical and economic evaluation of a biomass power plant.

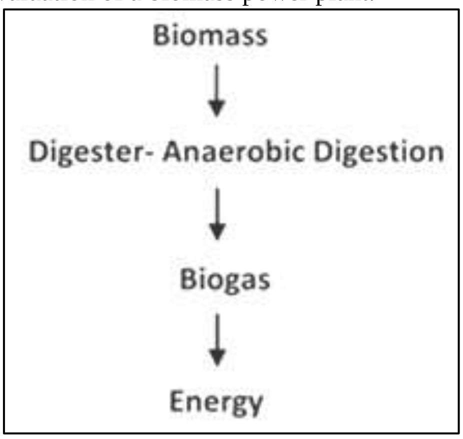

Fig. 2: Process of energy generation from biomass.

A biogas digester used to create anaerobic conditions for the decomposition to take place and to safely store the resulting biogas produced. The biomass is first fed to a digester as shown in fig.2 where some combustible gases mainly methane is generated and this gas may be used in the gas turbine for generation of electricity. The most well-known digesters are fixed dome digester and the floating dome digester. But both of these designs suffer from the brick and mortar. The problem caused by the leakage of gas creates a variable pressure that limiting its application in fixed dome type digester. Therefore the concept of floating dome digester has come into the picture.

Fluidized bed combustion (FBC) is a combustion technology used to burn solid fuels. Fuel particles are suspended in a hot, bubbling fluidised bed of ash, sand, limestone etc. through which jets of air are blown to provide the oxygen required for combustion. The fast and intimate mixing of gas and solid particles promotes rapid heat transfer and chemical reactions within the bed. FBC plants are capable of burning a variety of low-grade solid fuels, including most types of coal and woody biomass, at high efficiency and without the necessity for expensive fuel preparation (e.g., pulverising). In addition, for any given thermal duty, FBCs are smaller than the equivalent conventional furnace, so may offer significant advantages over the latter in terms of cost and flexibility. FBC reduces the amount of sulphur emitted in the form of SO_x emissions.

There are two reasons for the rapid increase of FBC in combustors. First, the liberty of choice in respect of fuels in general, not only the possibility of using fuels which are difficult to burn using other technologies, is an important advantage of fluidized bed combustion. The second reason which has become important is the possibility of achieving higher efficiency during combustion.

C. Common equipment

The thermal nature of the energy employed in both CSP and biomass combustion power plants make use of following common components.

- Turbine-generator set, where thermal energy is transformed first into mechanical energy and finally into electricity by means of an alternator. Since the working fluid in both the technologies is superheated steam, therefore a unique turbine-generator set can be shared by a hybrid solar-biomass power system.
- The other common elements in the Rankine cycle include pipes, valves, control devices, condenser, cooling towers and the deaerator. [1]

IV. DIFFERENT CONFIGURATIONS OF A CSP BIOMASS HYBRID POWER SYSTEM

In CSP and biomass power plants, heat is produced as an intermediate source of energy which is used to drive the turbine-generator set for the generation of electricity. This compatibility can be used to design a power plant that uses CSP during the day and biomass during periods of reduced irradiation. Hence, CSP Biomass combustion hybrid technology relies on the effective integration of a solar collector into the steam cycle of a biomass power plant.

The combination of these two technologies benefits from increased overall energy efficiency of the system, reduced investment per unit of power capacity as compared to CSP with molten salts heat storage and longer operating hours. The biomass and the solar thermal Rankine cycles can be interconnected using two different configurations like substituting the backup natural gas boiler for a biomass boiler or connecting the solar field and biomass boiler in parallel. [1]

A. Substitution of the Backup Natural Gas Boiler for A Biomass Boiler

The biomass boiler is designed to heat the HTF coming from the solar field instead of water. As in the original natural gas boiler, this kind of design requires the biomass boiler to have a very efficient dynamic response in order to adapt its working point to the variability of solar irradiation conditions. For this purpose, the biomass boiler usually includes a rapid response natural gas backup system. The configuration for the system is shown in the fig.3.

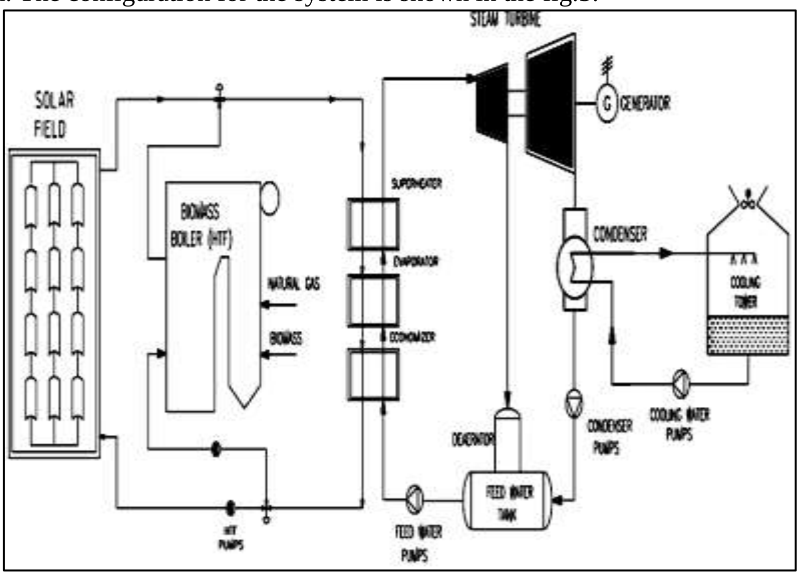

Fig. 3: CSP biomass hybrid configuration in which the natural gas boiler has been substituted by a biomass boiler[1]

B. Connecting the Solar Field and Biomass Boiler in Parallel

In this case both the solar and the biomass system are connected parallel for increasing the energy generation. In order to maintain appropriate steam conditions, the volume of water fed through the biomass boiler is adjusted depending on the solar irradiation and the steam generated by the solar field. The configuration for the system is shown in the fig.4.

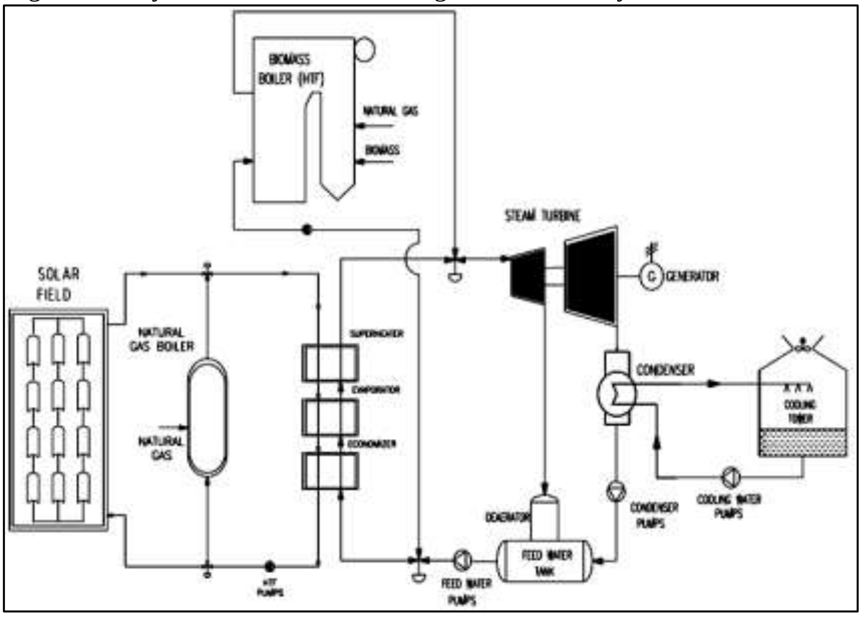

Fig. 4: Solar biomass hybrid configuration with CSP and biomass units set in parallel [1]

V. TECHNICAL ASSESSMENT OF CSP BIOMASS HYBRID TECHNOLOGY

The first parameter that needs to be considered in the design of the power plant is its power capacity. Since the economical consideration and the energy performance of the plant both are sensitive to scale factors. In general terms, larger plants benefit from higher energy efficiencies and take advantage of increasing economies of scale. However, large plants encounter difficulties to ensure a sustainable and stable supply of biomass feedstock. In this section, the technological assessment of both the configuration is discussed separately.

The plant configuration based on the substitution of the back-up natural gas boiler for a biomass boiler benefits from easier operation control and also from reduced construction costs, owing to the fact that no natural gas boiler is required. On the other hand, the main drawback of this configuration is the lower performance of the biomass cycle, due to the use of heat exchangers for the HTF fluid. The boiler substitution configuration is analysed in this section. Whenever possible, the power generation should be based on the CSP, since the fuel (solar irradiation) is free and the operating costs are minimised. [6] Natural gas can be used in the biomass boiler to provide primary energy during short transients, such as cloudy weather or transitions between biomass and CSP cycles. Biomass combustion will be used during longer periods when solar resource is unavailable, as for example during nights and winter day.

VI. ISSUES AND CHALLENGES OF BIOMASS SUPPORTED SOLAR POWER PLANT

- Capital cost investment of Biomass supported solar power plant is a big issue as both the biomass and solar plant individually has higher capital cost. Hybridization of both the plant tends to save the operating cost but still the capital investment is a bit higher.
- Maintenance and cleaning of biomass section is a big and problematic issue.
- Combination of solar power plant with biomass plant leads to the following advantages:
- Ensures 100% use of renewable sources to generate electricity.
- Progressive cost of a turbine generator set and associated balance of plant equipments required for a hybrid plant is less than a concentrated solar power plant.[5]
- The combination of solar and biomass plant also reduces the investment per unit of power capacity.
- The combine technology also results in the stable and continuous mode of operation.
- Thus combination of these two technologies increases the overall efficiency of the system.

VII. CONCLUSION

The proposed solar biomass hybrid systems have the potential of appropriate distributed power generation in any location within the country. This technique can increase the capability utilization issue of the plant and additionally economic in solar thermal energy conversion yet as having lower carbon footprint by not burning the biomass. The solar biomass hybrid systems are quite stable and have the potential of continuous mode of operation throughout the operational period. The storage system of solar thermal hybrid power plant contributes to avoid wasting biomass fuel which can increase the overall efficiency by 24%. [1] This concept of hybridization can be considered as the most vital mode to use solar thermal and biomass power in future.

REFERENCES

[1] J. Servert, G. Saw Miguel and D. Lopez, "Hybrid Solar - Biomass Plants for Power Generation, Technical and Economic Assessment", Global NEST Journal, Vol. 13, No. 3, pp. 266-276, 2011
[2] Gade Mahesh Babu, T.Srinivas, K.V.R.Naidu, " Integrated Biomass and Solar Thermal Power Plant - A Case Study," International Journal of Scientific & Engineering Research, Volume 4, Issue 8, August 2013,ISSN 2229-5518
[3] Singh PL, Ganesan S, Yadava GC. Performance of a linear fresnel concentrating solar device. Renew Energy 1999; 18:409–16.
[4] Desirable Features of Power Towers for Utilities
[5] [Online], March 2014, Available:
[6] http://energy.sandia.gov/?page_id=11728
[7] E.D. Larson, A review of biomass integrated-gasifier/gas turbine combined cycle technology and its application in sugarcane industries, with an analysis for Cuba,Energy Sust Dev, 5 (2001), pp. 54–76
[8] Kanwardeep Singh "Study of Solar/Biogas Hybrid Power Generation", (Guide: Mr. Souvik Ganguli), M.E. Thesis, Department Electrical and Instrumentation Engineering, Thapar University Patialia, July 2010.