Converting Waste Agricultural Biomass into Electrical Energy – Indian Perspective

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***Abstract*—India is one of the developing countries whose economy is largely based on agriculture. It constitutes the backbone of rural India whose inhabitants are more than 70% of total population. As a result, lots of agricultural wastes are generated and remain unutilized. Globally, 140 billion metric tons of biomass is generated every year from agriculture. This level of biomass can be converted to a massive amount of energy and raw materials. Equivalent to approximately 50 billion tons of oil, agricultural biomass waste transformed to energy can significantly displace fossil fuel, decrease emissions of greenhouse gases and supply renewable energy to some 1.6 billion people in developing countries, which still lack access to electricity. As raw materials, biomass wastes have striking potentials for large-scale industry and community-level enterprises.**

Keywords: Waste Agricultural Biomass, Renewable Energy, Electric Generation, Cost Effective

I. Introduction

Biomass takes the form of residual stalks, straw, leaves, roots, husk, nut or seed shells, waste wood and animal husbandry waste. Widely available, renewable, and almost free, waste biomass is an imperative resource. Moreover, there is always an increasing apprehension due to rapid exhaustion of fossil fuel resources for power generation and resultant pollution of the environment. Therefore, biomass is being considered as one of the substitute sources of electricity generation [1]. Rotten waste agricultural biomass emits methane and open burning by the farmers to clear the lands generates CO_2 and other local pollutants. Hence improper organization of waste agricultural biomass is contributing towards climate change, water and soil contamination, and local air pollution.

Besides, this waste is of high significance with respect to material and energy recovery. Biomass obtains its energy from the sun while the plants are growing. Plants transform solar energy into chemical energy during the process of photosynthesis. This energy is released as heat energy when the plant material is burned [2].

II. Conversion

In biomass power plants biomass fuel is burnt in boilers. The heat released from this process is used to heat and convert water into steam to turn a steam turbine which runs a generator to create electricity. Biomass is sometimes burned in combination with coal in boilers at power plants [3]. This process, called co-firing, is typically used to lessen air emissions and other ecological impacts from burning coal.

Biomass power plants release nitrogen oxides and a small amount of sulphur dioxide. The amounts emitted depend on the kind of biomass that is burned and the type of generator used. Although the burning of biomass also produces CO_2, the major greenhouse gas, it is considered to be part of the natural carbon cycle of the earth. The plants take up carbon dioxide from the air while they are growing and then return it to the air when they are burned, thereby causing no net increase. Biomass contains much less sulphur and nitrogen than coal; therefore, when biomass is co-fired with coal, sulphur dioxide and nitrogen oxides emissions are lower than when coal is burned alone. When the role of renewable biomass in the carbon cycle is considered, the carbon dioxide emissions that result from co-firing biomass with coal are lower than those from burning coal alone [4].

III. Modern Biomass Technologies in India

A. Heat and Steam from Sugarcane Leaf and Bagasse

Certain critical engineering design norms of the gasification system were first developed on a laboratory-scale model and then used to design a full-fledged commercial scale system with a thermal output of 1080 MJ/ h. This system comprises of a reactor, a gas conditioning system, a biomass feeding system and the instrumentation and controls [5].

1. ***Reactor:*** This was a downdraft, throatless and open-top reactor with an internal diameter of 75 cm and an active bed height of 1.25 m. It was designed for a heavy-duty cycle of 7500 hour per year operation. High temperature resisting firebricks conforming to IS 8 grade were used for the hot face followed by cold face insulation.
2. ***Gas conditioning system:*** A completely dry dust collection system eliminated altogether the problem of wastewater. This consisted of a high temperature char/ash coarse settler and a high efficiency cyclone separator. A specifically designed high temperature resisting induced-draft fan 3 ensured that the entire system is under negative pressure so that in the event of leaks, outside air got sucked into the system, but the combustible gas did not leak out. Thus, this design is very environment-friendly. The char-ash from the coarse settler and the cyclone was collected in barrels and emptied in an ash pit once every forty-five minutes. This char-ash which typically has a gross calorific value of 18.9 MJ/ kg can be briquetted to form an excellent fuel.

3. ***Biomass feeding system:*** This consisted of a scraper drag-out conveyor and a hopper to convey the biomass fuel from the storage pile to the reactor. The conveyor was completely enclosed.
4. ***Instrumentation and Control System:*** A Programmable Logic Controller (PLC)—based control system was designed to take automatic corrective actions under certain critical conditions. Thus, the biomass feeding and ash removal rates were fully controlled by this system. Besides, it also helped the operator in trouble-shooting by monitoring temperatures at various critical points in the gasification system. Automatic burner sequence controllers were provided for ignition of the producer gas.

The gasification system was extremely simple to operate. A cold start took about ten-fifteen minutes whereas a hot start was established in less than five minutes. Only two operators per shift of eight hours were required to operate the system, including the fuel and ash handling operations. The gasification system was successfully tested on sugarcane leaves and bagasse, sweet sorghum stalks and bagasse, bajra stalks etc.

B. Rice-Husk Based Gasifier

Biomass gasifiers capable of producing power from a few KW up to 1 MW capacity have been successfully developed indigenously. Indigenously developed small biomass gasifiers have successfully undergone stringent testing abroad. Biomass Gasifiers are now being exported not only to developing countries of Asia and Latin America, but also to Europe and USA. A large number of installations for providing power to small-scale industries and for electrification of a village or group of villages have been undertaken. The Biomass Gasifier Programme has been re-casted to bring about better quality and cost effectiveness. The programmes on biomass briquetting and biomass production are being reviewed and a new programme on power production linked to energy plantations on waste lands is proposed to be developed [5].

Installations: A total capacity of 55.105 MW has so far been installed, mainly for stand-alone applications.

1. A 5 x 100 KW biomass gasifier installation on Gosaba Island in Sunderbans area of West Bengal is being successfully run on a commercial basis to provide electricity to the inhabitants of the Island through a local grid.
2. A 500 KW grid interactive biomass gasifier, linked to an energy plantation, has been commissioned under a demonstration project.
3. A 4 X 250 kW (1.00 MW) Biomass Gasifier based project has recently been commissioned at Khtrichera, Tripura for village electrification.

C. MXP 10 Technology

These fuel fired boilers are offered in capacities upto 25 tons of steaming per hour. These boilers are offered in Shell and tube type construction, water tube construction and composite design. Thermax Solid fuel fired boilers are available designed to fire a wide range of solid fuels including agrowastes and other solid waste. These boilers are known for their ruggedness, and high efficiency, even when firing difficult fuels [5].

Process Description: The technology is a smoke tube; single pass boiler which can be fired on a number of fuels e.g. coal, husk, bagasse and wood. Depending on the type of fuel it has either a balanced draught or an induced draught system. The boiler consists mainly of three parts:

1. Refractory lined external furnace
2. Shell and tube exchanger pressure part.
3. Atmospheric water preheater (optional)

The furnace has a step grate or a fixed grate depending on the fuel e.g. for husk it has a step grate whereas for coal it has fixed grate. The fuel is charged through charging door to keep the fire going. The furnace is lined with refractory and insulation bricks. Furnace and steam generating section are placed in line. The draught is made available through the openings under the grate. In the case of coal firing an FD fan provides air for combustion. With the combination of FD and ID fan, balanced draught is maintained. Ash doors are provided to remove the ash from beneath the grate.

D. Biomass Gasifier

The biomass gasifier is essentially a chemical reactor where various complex physical and chemical processes take place. Four distinct processes take place in a gasifier, namely drying of the fuel (woody biomass), pyrolysis, combustion and reduction. Biomass is fed into gasifier at regular intervals. The equipment is designed in such a way that it takes air in controlled quantities, resulting in partial oxidation of biomass into producer gas. One Kg of biomass gets converted into 2.5 to 3.0 Nm^3 of gas with a calorific value of 1000-1300 Kcal per Nm^3, which would have the following composition CO- 15-20% CH_4- 1-4% CO_2-8-5%, N_2 –45-55%. The gas coming out of the gasifier is hot (200–2500C) and contains some contaminants, particulates and volatiles, which needs to be cooled and cleaned before feeding into the generators. The cooling cleaning system consists of scrubbers and associated accessories. Cold clean gas produced is fed to engine along with air. Woody biomass available in plenty is collected and transported to the gasifier through a skip charger [5].

Environmental Considerations: It converts a traditional low quantity fuel inconvenient for use into high quantity, combustible gaseous fuel with associated convenience. Such conversions are relatively at high efficiencies and result in total convenience and process control. Almost all environment pollution associated with biomass use can be eliminated. Initial investment and also the cost of generation of energy are just about the lowest amongst all known alternatives. Gestation period is very less and can be completed within 3 to 6 months.

A 10-15 MW agri-waste based power project has been set up jointly by **Punjab Biomass Power, Bermaco Energy, Archean Granites and Gammon Infrastructure projects Limited in Punjab.** The project uses locally available agricultural waste such as rice straw and sugar cane trash for fuel [6]. The total annual fuel requirement is around 120,000 tonnes of biomass, all of which will be acquired locally. Punjab has about 20 million acres under paddy yielding 100 million tonnes of rice straw. As rice straw is a poor fodder and fuel, farmers burn it in the fields and make way for the Rabi wheat crop. But now these wastes are being used for generating electricity. The project is expected to provide additional income to 15,000 farmers from the sale of agri waste. The project will be a major landmark in environment protection-converting agricultural waste to energy. Secondly, it will trim down the release of smoke and other pollutants caused by burning 100 million tonnes of wastes which could be used for earning carbon credits.

IV. Advantages

Sustainable production and utilization of biomass in electrical power generation can also solve the problems of rural unemployment, utilization of wasteland, and transmission losses in grid network [7]. Therefore, the system of biomass-based power generation is being given precedence in most of the developing nations including India. Unlike other renewable substances biomass supplies, pre-dried up to about 15% moisture content, can be stored for a much longer period of time without any complications. Besides electricity supply to the national grids, biomass offers great opportunities for decentralized power generation in rural areas at or near the points of use and thus can make villagers/small industries self-dependent in respect of their power requirements. It is necessary to find out the various properties like calorific value, chemical composition, reactivity towards oxygen, bulk density, etc to exploit biomass species in electricity generation.

V. Future of Biomass Energy in India

Future of biomass energy depends on providing consistent energy services at competitive cost. In India, this will happen only if biomass energy services can compete on a fair market. Policy priorities should be to orient biomass energy services towards market and to reform the market towards fair competition. Most cost-effective option is exploitation of waste materials. Potential availability of agro residues and wood processing waste in India can sustain 10,000 MW power [8]. Constant supply of biomass shall require production of energy crops (e.g., wood fuel plantations, sugar cane as feedstock for ethanol) and wood plantations for meeting growing non-energy needs. Land supply, enhanced biomass productivity, economic operations of plantations and logistics infrastructure are significant areas which shall determine future of biomass in India.

VI. Conclusion

This paper emphasized on possible use of waste agricultural biomass resources currently available in India for the production of electrical energy. There is a variety of biomass resources existing in the country and there is also huge opportunity for their conversion to various types of biofuels using different biomass conversion technologies. The availability of different types of agricultural crop residues, forest residues and wood processing waste makes them possible biofuel feedstocks. Also, the organic part of municipal solid waste, together with animal manure could play a key role as potential cellulosic feedstocks for the production of biogas.

The adoption of biomass as fuel for electricity generation in India can ease the financial strain relating to the heavy burden of fossil fuel costs and also develop local source of revenue for the people within the production chains. With the very high potential for biofuel production, the Government as well as private investors should take steps towards investing in agriculture for the production of energy crops and establishment of processing units for agricultural residues.

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