Electricity from Rice Husk: A Potential Way to Electrify Rural Bangladesh

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Abstract- The sustainable economic development of a country stands on the sufficiency of electrical energy. So, to compete with the rest of the world, Bangladesh should have sufficient electricity facilities to carry on its economic development. To make a country a developed one, the facilities of electricity should be reached from door to door. As Bangladesh is an agricultural country, several kinds of agricultural wastes are available here. So, this huge amount of agricultural waste can be a source of electricity generation in Bangladesh. Rice husk is one of the potential agro wastes which can be used as raw material to generate electricity, only if it can be processed properly and systematically. The purpose of this paper is to make available an idea of electricity generation from rice husk in the rural areas of Bangladesh. The rice husk based small & medium power plants are very much useful to generate & supply electricity in the rural areas. In this paper the availability of rice husk in Bangladesh, the different feasibility studies and the main process which can be used to generate electricity from rice husk are discussed. The main purpose of this paper is to assist the journey of Bangladesh towards development. This paper will help both the Govt. & private sector to establish rice husk based power plant in rural areas of Bangladesh. Finally it is hoped that this paper will be a suitable guideline to mitigate the huge demand of electricity in the rural areas of Bangladesh.

Keywords Rice husk, gasification, gas turbine, power plant, clean energy.

1. Introduction

The demand of electricity is increasing all over the world. In Bangladesh the peak demand of electricity is 8349 MW and by the year 2021 it will be 18838 MW [1]. To mitigate this huge demand, Govt. has to search for new ways of electricity generation. Again the whole world is now searching for a greener way to generate electricity. In this perspective, electricity from rice husk can be a suitable option. Bangladesh is an agro based country. The main crop of this country is paddy. Aman has been estimated to be produced 12.897 million metric tons in 2012-2013 whether in 2011-2012 it was 12.798 million metric tons. [2]. so, rice husk is very much available here. By using this huge amount of rice husk, we may generate a good amount of electricity & can distribute it to the rural areas at a cheaper rate. Traditionally rice husk is used as biomass fuel in most of the rice mills in our country. They use it to make the rice dry. This burning process of rice husk in such an unscientific way causes huge amount of emission of CO, CO2 in the atmosphere which are the main culprits of green house effect. So, if we use this huge amount of rice husk in a scientific way to generate electricity, then we will be able to reduce the emission greenhouse gas and at the same time be able to generate our demanded electricity.

2. Rice Husk: Characteristics & Availability

Rice husk can be used to generate electricity. The characteristics & chemical composition of rice husk has made it easy to use it for electricity generation. The availability of rice husk is also discussed in this point to have an overview of the scenario of the current rice husk production and its availability in Bangladesh.

2.1. Characteristics & chemical composition of rice husk

The approximate amount production of rice husk globally is 600 million tons [14].The outermost layer of paddy is called rice husk. It is also known as rice hull.

Usually in rice mills it is separated from the rice. Rice husk has some specific characteristics which has made it easy to be used as an energy source.

- The average caloric value of rice husk is 3410 K Cal/kg [15].
- 1 ton of rice paddy can produce 220 kg of rice husk [16]
- Rice husk is easily collectable at a very low cost.

A typical analysis of the chemical composition of given in the table [17] below:

Table 1: Chemical composition of rice husk

Property	**Range**
Bulk density (kg/m3)	96-160
Hardness (Mohr's scale)	5-6
Ash,%	22-29
Carbon, %	≈ 35
Hydrogen,%	4 - 5
Oxygen,%	31 - 37
Nitrogen,%	0.23 - 0.32
Sulphur,%	0.04 - 0.08
Moisture,%	8 - 9

2.2. Availability of rice husk in Bangladesh

Using rice husk for electricity generation depends on the availability of raw material and the technology used for conversion rice husk to energy. According to the Rice mills owners association of Bangladesh, there are one hundred thousand rice mills and 90% of these rice mills are located in four cluster areas. These four cluster areas are Dinajpur (North Bengal), Sherpur (Near Bogra), Ishwardi and Kaliakoir (Near Dhaka). Taking an average (lower- mid) capacity range of about 100-200 KW, there is a 50-100 MW power markets in these cluster areas [3]. Total rice production in Bangladesh is now producing about 25.0 million tons per year to feed her 135 million people [4]. Total amount of available husk = 5 million ton/year. [Assume 20% of weight is converted into husk] Total amount of available husk per day = 13698.63 kg/day. For a steam turbine power plant consumption of rice husk is 1.3 kg per kWh electricity as reported by Singh [5]. On the other hand for a gasification power plant consumption of rice husk is 1.86 kg per kWh electricity generation [6] [7]. According to the theorem a steam turbine power plant can produce around= 13698.63/1.3 kWh =10537.41 kWh per day and a gasification power plant can produce= 13698.63/1.86 kWh =7364.85 kWh per day. A survey based on majority of paddy production area shows the potential power capacities is estimated to be 41450 kW in the four selected zones considering the steam turbine technology, whereas the corresponding power capacities is estimated to be 29050 kW considering gasification technology[7].

Table 2. Electricity generation capacity based on rice husk availability

Rice processing zone	**Available husk**	**Potential of electricity generation**	
	from rice mill. '000' ton/yr	Boiler plant kW @1.3 kg husk/kWh	Gasification plant kW @ 1.86 kg husk/kWh
Dinajpur	82.90	7250	5150
Ishawrdi	121.21	10750	7500
Bogra	58.69	5200	3600
Naogaon	192.55	18250	12800
Total	**455.35**	**41450**	**29050**

3. Procedure of Electricity Generation from Rice Husk

There are several methods of generating electricity from rice husk. Among some effective ways, here power generation by rice husk gasification is adopted and the system is designed in such a greener way so that the system evolves absolute zero emission. For the process to discuss elaborately a basic block diagram is shown in Fig. 1.

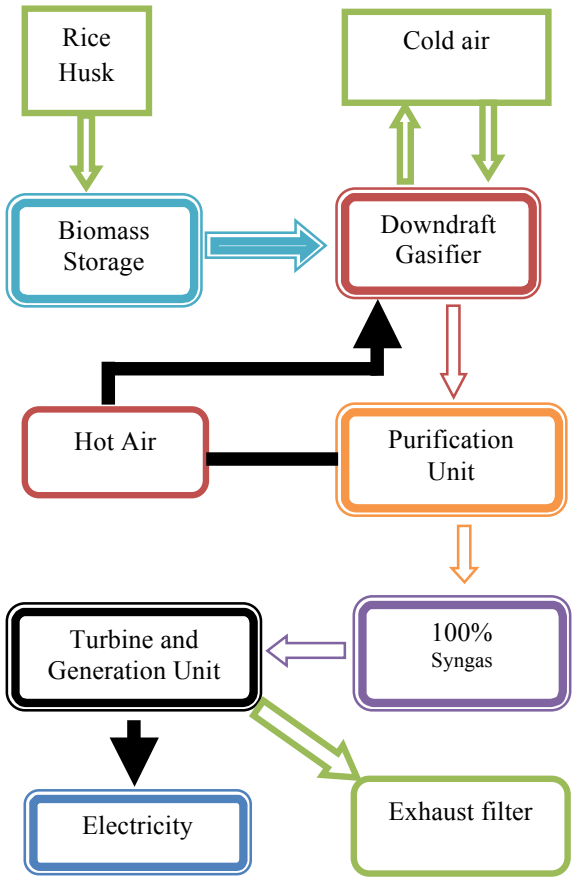

Figure 1. Block diagram of a rice husk electricity production unit

From the figure it is clear that the process starts from the biomass storage where the rice husk is put for the process. It

is nothing but a reservoir of rice husk. After preserving there, the rice husk is conveyed to the gasifier where it goes through some certain chemical reactions to produce syngas. There are a few types of gasifier are present in the market which have different sets of pros and cons, such as fixed bed updraft and downdraft gasifier, twin fire fixed bed gasifier, fluidized bed gasifier and bubbling bed gasifier. However the cheapest among these gasifiers is downdraft gasifier and this gasification chamber produces a product gas with very low tar content. So for utilizing this benefit, for small-scale rice husk biomass plant fixed-bed downdraft gasifier is ideal. Here, biomass fuel is fed at the top of the reactor/gasifier. Then as the fuel moves downward, it reacts with air (the gasification agent). The suction of a blower or an engine supplies the air needed for the reaction and then the air is converted into combustible producer gas through a complex series of reactions like oxidation, reduction, and pyrolysis [9]. The major processes are described further below.

3.1. Downdraft Gasification

A downdraft gasifier is a chamber in which both the gas and the solids flow in the sane downward direction. Due to the downward flow this type of gasifier produces cleaner gas than any other method like updraft gasification chamber. It is because in downdraft gasifier all the produced tar is secondary whereas updraft gasifiers produce primary tars. Moreover the downdraft nature also allows for grater conversion rates as gravity forces the material to flow through the entire gasification chamber [18]. It has also some limitations on controllability for large diameters or power output [11, 12]. Due to the formation of preferential channel being at the fuel bed, it prevents the tar rich stream to move from the pyrolysis region to enter the combustion region. By using slow-rotating paddles, uniform distribution of particles in the bed is provided and thus this problem is extinguished [13]. A schematic diagram of a downdraft gasifier is given in Fig. 2.

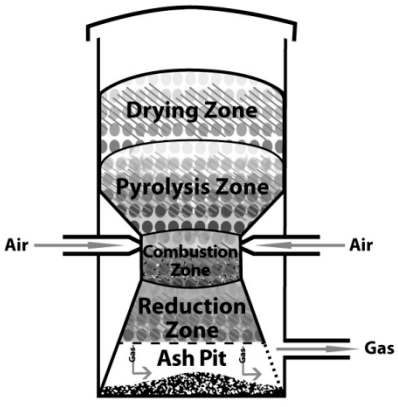

Figure 2. Schematic diagram of a downdraft gasifier

From the figure it is clear that rice husk is entered in the system from the top of the unit and the process progresses at it descends. The actions involved in the full process are drying, pyrolysis also known as devolatilization and combustion also known as gasification. In the drying process the rice husk is dried at high temperature, which results steam. This steam is later mixed with gas flow and creates some water gas chemical reaction if the temperature is sufficiently high. Now the next step is pyrolysis, where cracking and burning of most of the primary tar (made of oxygenated organic compounds) content is done. It is also called flaming pyrolysis [10] or de-volatilization. In this zone the temperature is around 200-300 degree Celsius and char is produced by burning process. The char is then forwarded to the combustion zone where it undergoes gasification reactions with steam produced in the drying process and air. The basic reactions which occur in the entire process are given below.

$$C + O2 \leftrightarrow CO2 \quad \Delta H = -393.5 \text{ kJ/mol} \tag{1}$$

$$C + H2O \leftrightarrow H2 + CO \quad \Delta H = -131.3 \text{ kJ/mol} \tag{2}$$

$$CO + H2O \leftrightarrow CO2 + H2 \quad \Delta H = -41.1 \text{ kJ/mol} \tag{3}$$

$$4CO + 2H2O \rightarrow CH4 + 3CO2 \quad \Delta H = -520 \text{ kJ/mol} \tag{4}$$

While the char and volatile products reacts with air, Carbon dioxide and a small amount of Carbon monoxide is produced in reaction (1) and the reaction emits heat which helps the subsequent gasification reaction. Then again the Carbon from char and steam reacts and produces carbon monoxide and hydrogen. As this reaction (2) is a reversible one, after a certain time the amount of carbon, steam, carbon monoxide and hydrogen becomes equal and the reaction reaches equilibrium condition. Then a limited amount of air is introduced in the system which forwards the burning process and produces some more carbon which again restarts the reaction (2) and produces more carbon monoxide and energy. Then the reaction (3) takes place and produces hydrogen and carbon dioxide. Further reactions (4) produce methane and excess carbon dioxide from residual water and carbon monoxide. And this final reaction increases the resident time of the reactive gases and organic materials as well as heat and pressure [19, 20]. In the model (Fig. 2.) it is seen that below the combustion zone there is a reduction zone from where the gas is collected out of the gasification chamber. There is an ash pit where the ash of rice husk is accumulated and is ready for disposal.

3.2. Purification Unit

To make the purification system more environmentally friendly here it is suggested to use the dry type purification unit. Commonly used gasification system uses a wet type purification unit which follows the method of direct washing. It washes the producer gas with direct water to get rid of particulates, tar etc. It works as the cooling system for the producer gas at the same time. This type of purification unit requires a large amount of water and it also pollutes water as water come direct contact with the gas. The tar mixes with the water and usually no precaution is taken to purify the water. Moreover this water may be used repeatedly, so after a certain time it becomes completely contaminated. So an extra water purification system is necessary for this kind of units. As the water cools the gas, it becomes hot and it emits vapour which contains PAHs (polycyclic Aromatic Hydrocarbons) and ammonia. Also this kind of systems does not have heat recovery option, so efficiency is less. To eliminate these barriers, this exclusive dry gas purification unit is introduced. This system excludes all the limitations of the wet type purification unit. It does not need any water to

purify the gas, so no water pollution is present here; also the gas processing happens in the chamber so there is no foul smell in the air of the plant area. No liquid tars, no evaporation of contaminated water with ammonia and other gases makes this system air as well as the environment pollution free. The maintenance needed of this type of purification system is minimum as there is no slug production is present and the efficiency is maximum as the heat from the producer gas is recoverable and it can be reused for drying the rice husk or heating the gasifier. This type of purification unit is more reliable as it allows a smooth operation of the turbine to generate electricity. Below is the specification of purified gas from the system.

Average CV > 1100-1200 kcal/Nm3

Tar content < 5-10 mg/Nm3

Particulates < 5-10 mg/Nm3

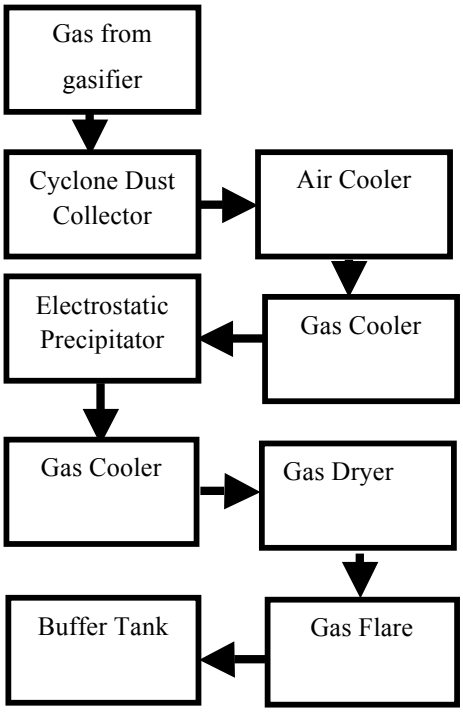

Figure 3. Block diagram of purification unit

The dusts are removed in dry format from the ESP, so dust processing is convenient. The ammonia removing process from gas is dissolution and it produces small amount of residue (condensate) to handle. From the residue ammonium salt can be recovered and can be used as good fertilizer [8]. The process shows clearly the steps to purify the syngas received from the downdraft gasifier. The produced gas coming from the gasifier usually contains contaminants including dust, ash, coke, tar etc. The contaminants are removed from the gas by the purification system to ensure normal operation of the turbine in which it will be fed next.

3.3. Turbine and Generation Unit

This unit is the power generation section of the system. Here the syngas collected from the purification system is used to generate electricity. Here two types of turbines can be used: gas turbine or steam turbine. If steam turbine is to be used, it will require a boiler where water will be heated and made steam using syngas and the efficiency will not be so high. So here it is best to use gas turbines. The efficiency of gas turbine is far better than the previous process [26]. Here in this process, the syngas is taken into the combustion chamber, mixed with air and then combusted. It produces flu gas, which is flown through the blades of the turbine. The turbine absorbs energy from the high pressurized hot gas and rotates. As a result the gas becomes low pressure which will be exhausted. Now this exhaust gas will be passed through a chimney which includes a high featured filter and ejected into air. The turbine shaft is connected with a generator which generates electricity while the turbine rotates. The figure below shows the diagram of electricity generation unit. In most of the implemented projects there is no focus on the exhaust system. Here it is suggested to use a smart exhaust filter system which will downsize the emission of CO2 and other component in the air.

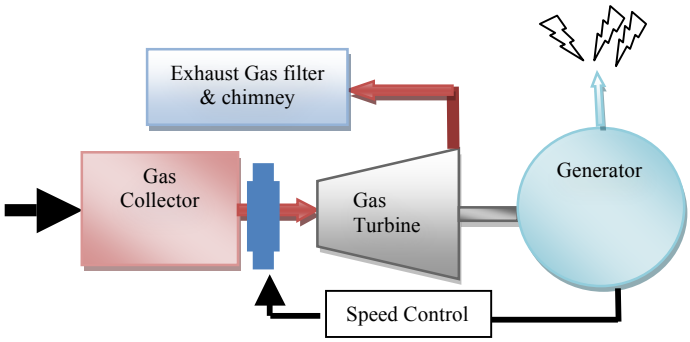

Figure 4. Schematic diagram of generation unit

4. National & International Case Study

Electricity generations from rice husk projects are being popular and implemented now days, both nationally & internationally. So it is more practical to discuss about a national & an international case study to make the thing clearer. Both a national & an international case study are discussed below.

4.1. National Case Study

This plant is fully operational.

Name: Dreams power Ltd

Location: Kapasia, Gazipur, Dhaka, Bangladesh

Project Sponsor: Infrastructure Development Company Ltd. (IDCOL)

Equipment Supplier: Ankur Scientific Energy Technologies Pvt. Ltd. of India. Some parts are also come from Germany & Italy.

Main Parts of The Project: Two downdraft gasifier, a dual fuel generator, four electric motors & a spread pond.

Capacity: 250 KWh

Cost: Tk. 2.50 Crore.

Support: This plant provides electricity to 300 households and commercial entities of that area [24].

4.2. International case study

This plant is fully operational input is combined with coal.

Name: Vandana Vidhyut Limited

Location: Sirgitti Industrial Area, Bilaspur, Chhattisgarh.

Project Sponsor: Self sponsored project of VVL.

Equipment Supplier: Vandana Vidhyut Limited.

Main Parts of The Project: One high pressure boiler of 35 tph, 66 kg/cm2, 5000C and a steam turbine generator (STG) single bleed cum condensing type.

Capacity: 7.7 MW

Cost: 254.85 million Indian Rupee.

Support: 10% of the generated electricity is used for auxiliary operation and the rest is supplied to the grid [25].

5. Users and Benefits of the Project: By Products of the Process

The main users of this project are the rural people. In Bangladesh there are thousands of people who are deprived of the benefits electricity. Again there are some remote areas where it is very costly to setup conventional power plant or connect national grid connection to supply electricity. In this field, such kind of low or mid capacity based electricity generation by using natural resources are very much effective. Most of the people in Bangladesh live in rural areas & hundreds of tons rice is produced in these rural areas. So if the authority makes it happen to generate electricity from rice husk in these rural areas, then the lifestyle of these rural people will surely be developed which will ultimately help our economic development to run faster. Thus the potential beneficiary of this electricity generation will be the whole country.

To elaborate the benefits of such kind of electricity generation, the first thing that comes to consideration is that the process is very much eco friendly as it is a form of clean energy. Again the costing of such kind of low or medium capacity based rice husk based power plant is not so much. It is very easy to install & need less maintenance (only 4 / 5 people are enough to run such kind of power plant). It needs less space to install and the technology used here is very common. So such kind of power plant can be run by local people and can be installed in any remote area which is one of the main benefits of it.

Another advantage of the procedure of electricity generation from rice husk is that amorphous silica (SiO2) is produced as byproduct in this process. It makes the project economically more viable to implement. The amorphous silica that is produced as byproduct is rich in silicon as rice husk has high ash content [21]. So this silica can be used widely in glass, ceramics and cement industries etc. Cement industries can produce better quality cement production or make unique quality concretes which have high strength, more durable and low permeable. This ash also can be exported if the transport facilities are viable because the price of rice husk ash is as high as $500/ton [22] [23].

6. Obstacles

There are many obstacles which makes it difficult to implement such kind of power plant especially in Bangladesh. In Bangladeshi perspective the obstacles are:

Loan Facilities: The loan facilities to establish such kind of non conventional power plant are not available in Bangladesh. Different Govt. & private Bank and finance organization does not get interest to fund such kind of projects. But recently with the help of Infrastructure Development Company of Bangladesh (IDCOL) different financial organizations are coming up to fund such projects.

Attitude Barriers: The local people are not concerned about the technologies that are used in such power plant. So they are not interested to establish such power plant.

Availability of rice husk: Though Bangladesh is a rice producing country, rice husk is not available all the year round. Especially in the rainy season the rice mills cannot continue their work properly. As a result the supply of rice husk is almost off in that particular season. This time is called scarcity time. Again the rice mill owners are not very much willing to supply the calculated demand as they use this rice husk for their own fuel purpose. It is not economically viable for them to sell the rice husk at a cheaper rate and to buy fuel at a higher cost. Again, the poor people of Bangladesh use briquette made by rice husk as household fuel. So, there causes an Attitudinal Barriers to have sufficient rice husk for electricity generation purpose.

Efficiency: The main problem electricity generation from renewable energy sources is that this is not as efficient as generation of electricity from conventional power plant. This is also true for the process of electricity generation from rice husk.

7. Conclusion

It is impossible for any country to keep pace in development activities with other developed countries if it is not independent in power generation sector. Bangladesh is a developing country. So it is very much important for Bangladesh to ensure its own energy security. The conventional energy sources are decreasing day by day. So now it is high time we should take the renewable energy sources in action. Electricity generation from rice husk can be a better alternative of conventional energy sources in Bangladesh perspective. It is comparatively cheaper to install, easy to handle. In Bangladesh there are several types of obstacles to establish such kind of non conventional power plant. But there is no other way for Bangladesh to generate electricity but from renewable energy sources. So, Govt. & private organizations should come forward to inspire & to fund such kind of projects.

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