DESIGN AND FEASIBILITY OF MICRO HYBRID BIOMASS PLANT USING MAGNETO HYDRODYNAMIC GENERATOR AND THERMOELECTRIC GENERATOR

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ABSTRACT

Due to modernization, the power demand is increasing day by day resulting in a wide gap between supply and power demands. Efforts may be oriented towards the search of new sources of energy and has led to the growth of other non conventional methods using renewable sources. As a result, rush to biomass systems have been promoted around the globe at a very large scale as biomass is used as a raw material either in primary or secondary processing units. Nevertheless, plants using biomass as raw material are promoting problems like carbon dioxide emissions and methane gas emission which are threat to earth's ozone layer. High ash content and heat release to environment are the harmful effects of biomass plant. In order to get optimal generation conditions, cogeneration of biomass plant is done so as to provide clean energy to environment. For this reason, biomass cogeneration is done using MHD generator, thermoelectric generator so as to increase the reliability and efficiency of the system. Normally the efficiency of boiler is 25-35% but by using the cogeneration, efficiency has increased to 65-85% because flue gases obtained from burning of raw material are cycled again to boiler after passing through MHD and TEG generator. As a result the boiler will need less energy to increase its internal temperature thereby increasing the efficiency of boiler. The flue gases obtained after burning the fuel in boiler is fed to TEG, from where they move to MHD generator. The seeding material is added as the flue gases enter the MHD generator so as to increase the electrical conductivity of the gas. Now, again the flue gases are fed to boiler and consequently the cycle is completed. The output from TEG is utilized by the cogeneration plant itself, so as to fulfill power requirements of the plant such as in cooling systems; fans etc. leading to less power consumption. The other two outputs i.e. from turbine and MHD generator are fed to the grid so as to meet the power demands.

CHAPTER-1

INTRODUCTION

1.1 ROLE OF ENERGY

Energy plays a very important role in everyday life and is the most important resource in the economic growth of a country. In every sector i.e. industrial, agricultural, transport, commercial and domestic; electrical energy is a must. Due to industrialization and urbanization, the demand of energy is increasing day by day and for the same, rush to alternative sources of energy production are increasing. Modernization increases the productivity in industry which is dependent on electrical energy utility and these demands can be fulfilled through energy generation resources. Energy is divided into many resources, such as renewable resources, non-renewable resources and fossil fuels, especially oil and natural gas which are present in limited amount. Many searches are going on towards the usage of new sources of energy which further leads to the promotion of alternative energy sources using solar, wind, biomass etc. This has led to the increase in the electricity generation through non-conventional resources with the objective of sustaining the non-renewable sources of energy. Moreover, along with the generation of electric power they also help in overcoming the effect of global warming and promote healthy environment. Hence it is necessary to generate more and more power so as to fulfill the increasing demands of energy.

1.2 RENEWABLE SOURCES OF ENERGY

Renewable resources of energy are those resources which can be renewed again and again and are present in nature in large amounts. Therefore it is the best option for energy generation. Different forms of renewable resources are:-

1. Wind energy
2. Solar energy

3. Geothermal energy

4. Hydroelectric energy

5. Biomass

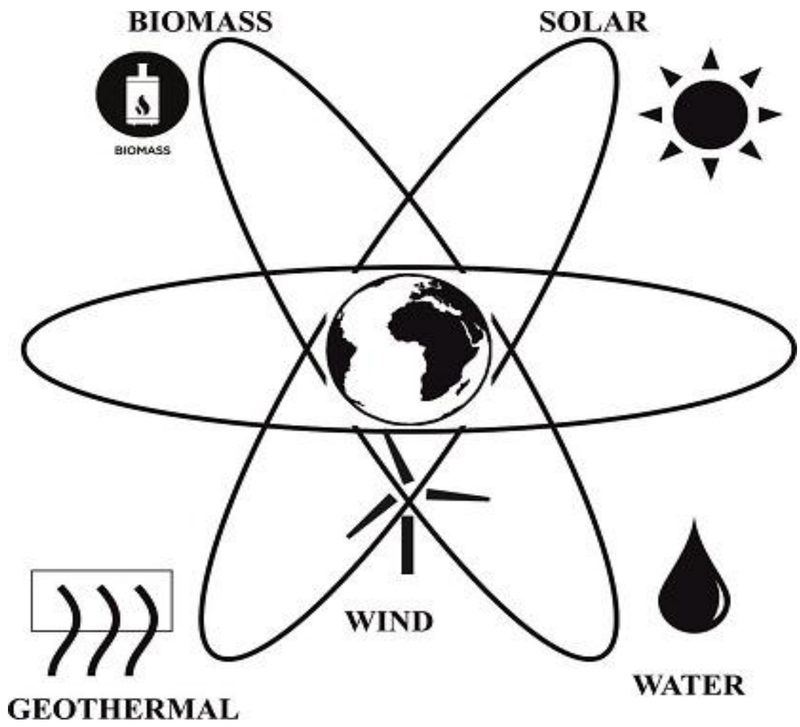
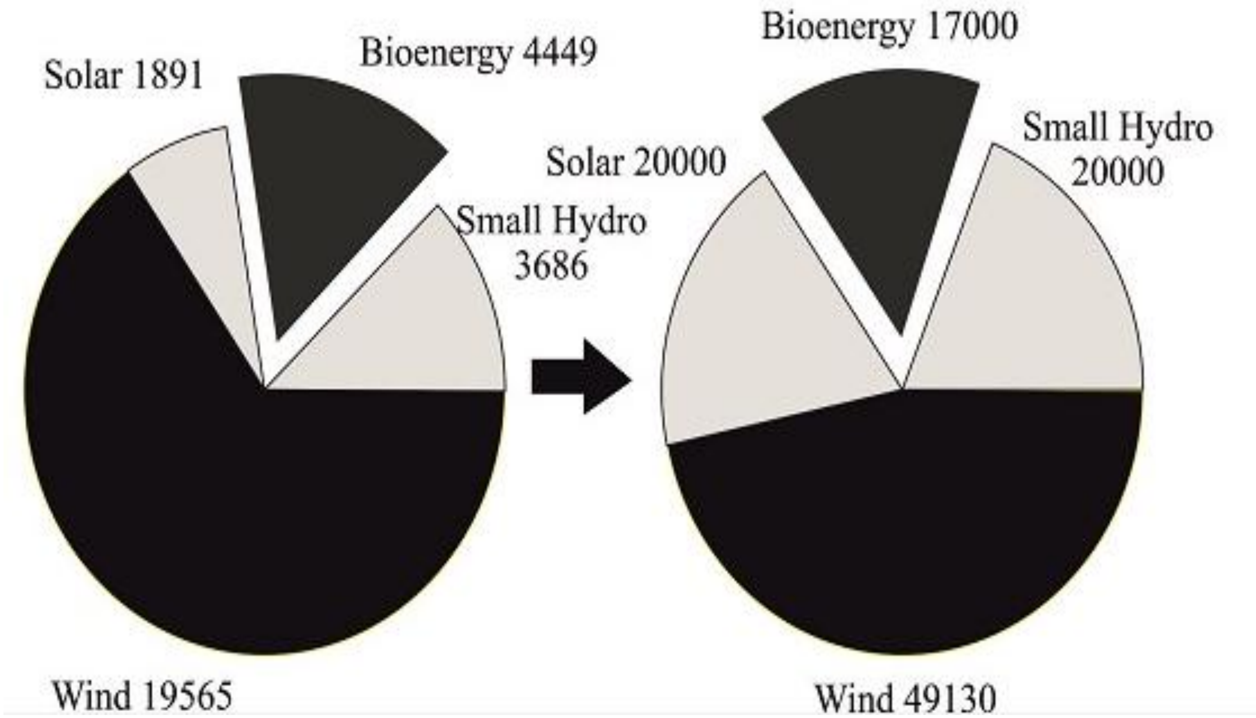


Fig 1.1 Renewable sources of energy

1.2.1 POSITION OF RENEWABLE ENERGY IN INDIA

India is rich in renewable resources like solar, wind, biomass , hydro and cogeneration and for further development of country, emphasis must laid on the utility of these resources so as to accomplish the growing demands of energy . Since from the past years many plans have been promoted to conserve the resources, consequently there has been high level of their usage; and therefore building a brighter future. In the figure 1.2 the future of energy generation using renewable sources in India is shown:-



Installed capacity of renewable resources Potential of renewable resources up to 2032

Fig 1.2 Expected growth potential of renewable in future

The above figure shows the expected future of using renewable resources to meet the growing demands. In the first figure the installed capacity of renewable resources in India is shown and further the expected installation of projects using renewable resources is depicted in solar, biomass and hydro plants have bright future.

For the same, searches are going on towards the usage of new sources of energy which lead to the promotion of alternative energy sources using solar, biomass, wind etc. this has led to the increase in the electricity generation through non-conventional resources with the objective of sustaining the non-renewable sources of energy. Hence from this it is concluded that biomass has a promising future in upcoming years, thus promoting high scope.

The state wise look of renewable energy status in India is given in the Table 1.1.

Table 1.1 Renewable energy position of different states of India

State name	Wind Power(MW)	Small Hydro Power(MW)	Biomass Power (MW)	Bio-energy Bagase Cogeneration (MW)	Bio-energy-Waste to Energy (MW)	Total
Andhra Pradesh	14500	987	582	301	132	16502
Arunachal Pradesh	240	1350	9	NA	NA	1599
Assam	120	240	212	NA	8	580
Bihar	150	230	620	300	80	1380
Chhattisgarh	312	1108	234	NA	24	1678
Goa	NA	8	24	NA	NA	32
Gujarat	35071	200	1222	351	120	36964
Haryana	94	100	1340	350	25	1909
Himachal Pradesh	65	2350	150	NA	2	2567
Jammu & Kashmir	5685	1440	45	NA	NA	7170
Jharkhand	95	210	90	Na	10	405
Karnataka	13593	4150	1230	450	NA	19423
Kerala	837	704	1044	NA	36	2621
Madhya	2932	820	1365	NA	35	5152

Maharashtra	5965	795	1890	1250	288	10188
Manipur	56	109	15	NA	75	255
Meghalaya	85	230	15	NA	2	332
Mizoram	NA	170	1	NA	2	173
Nagaland	16	199	10	NA	NA	225
Orissa	1432	298	256	NA	24	2010
Punjab	NA	441	3172	300	44	3957
Rajasthan	5060	57	1039	NA	62	6218
Sikkim	98	267	2	NA	NA	367
Tamil Nadu	14152	660	1070	450	152	16484
Tripura	NA	47	5	NA	2	54
Uttar Pradesh	1260	452	1620	1250	175	4757
Uttarkhand	535	1709	25	NA	5	2274
West Bengal	25	340	396	NA	148	909
Daman & Diu	4	NA	NA	NA	3	7
Chandigarh	NA	NA	NA	NA	6	6
Delhi	NA	NA	NA	NA	131	131
Pondicherry	130	NA	NA	NA	3	133
Dadar& Nagar Haveli	NA	NA	NA	NA	NA	NA
Andaman & Nicobar	365	8	NA	NA	NA	373
Lakshadweep	NA	NA	NA	NA	NA	NA
Others	NA	NA	NA	NA	1023	1023

Total	103624	19779	17683	5002	2617	106398

Source: MNRE

1.2.2 POSITION OF RENEWABLE ENERGY IN PUNJAB

PEDA (Punjab Energy Development Agency) is an agency established for the promotion and development of renewable energy projects and energy conservation program in Punjab. This agency helps to enhance the status of state energy production. Table 1.2 shows the renewable energy status of Punjab of the year 2015.

Table 1.2 Installed renewable Energy position of Punjab (2015)

S.No	**Renewable energy system type**	**Installed Capacity(in MW)**
A.	**Grid Interactive Renewable Power**	
1.	Biomass Power	55 .00
2.	Wind Power	–
3.	Small Hydro Power	Installed Capacity-49.50 Capacity under installation- 35.85
4.	Solar Power	9.00
B.	**Off Grid Renewable Power**	
1.	Biogas plants	2.5
2.	Biomass cogeneration	390
3.	Solar Panel Voltage systems(> 1 k W)	810 k W

From the previous data it is clear that, projects based on renewable resources are promoted, leading to power conservation. This thesis discusses the usage of one such renewable resource, i.e. BIOMASS; used as a cogeneration plant to generate electricity.

1.3 BIOMASS - A FIRM UTILITY

The left out of crops like sugarcane residues, husk, rice straw, rice husk, wheat husk, wheat straw etc. and industrial residues like sawdust, wood off-cuts etc. are generally referred to as biomass and the energy released from these waste materials is known as biomass energy. It is a perfect renewable fuel for Combined Heat and Power (CHP) applications as biomass is publically acceptable and is available in large quantities in agricultural, industrial, urban areas. Biomass has many properties like renewable, widely available and carbon neutrality due to which it makes biomass as an incredible energy source for power generation. Moreover it is capable of providing continues power supply and plays double role in green house mitigation both as energy source and carbon sink.

1.3.1 DIFFERENT BIOMASS MATERIALS

For biomass used as a fuel, different forms of materials are required which are generally residues like agro-industrial waste and are present in huge quantities. Therefore various materials available as biomass are:-

Virgin Wood- The left out of forestry and wood processing units comes under the virgin wood

Energy Crops- The high yield crop grown especially for providing heat energy comes under energy crops. It consists of popular, silver maple, green ash, sweet gum etc.

Agricultural Residues- The waste from agricultural crops after harvesting comes under agricultural residues. Examples are soya been, wheat husk, paddy husk, wheat straw, paddy straw, sugarcane husk etc.

Aquatic Crops- Wide range of plant materials that are found in water such as algae, giant kelp and other sea weeds are aquatic crops and can be used as biomass fuel.

Animal Waste- Animal waste can be collected through farms and animal dispensation operations and can be used as biomass fuel as they contain special organic matter having good calorific value.

Municipal Waste- Commercial and residential wastes contains significant amount of wastes which can be used as raw material including waste papers, cardboard, wood waste and yard waste etc.

Industrial Waste- Industrial waste includes the wastes from processing industries which includes wood wastes, pulps, saw husk, etc.

Forestry Residues- The material resulting from forest residues programs containing all the forest wastes are collected and are used as biomass raw material.

All these waste materials are used as fuel in biomass plants and are present in abundance, hence lead to many advantages like energy conservation as well as promoting clean and healthy environment. As a result using biomass as a energy source is a solution to the alternate source of generating electrical energy and further encourage a green environment.

1.3.2 BIOMASS CONVERSION TECHNOLOGIES

The technologies that convert the biomass fuel into electricity (power) using boilers, turbines, gasifiers, fuel cells etc. are known as biomass conversion technologies. Some of the techniques are:-

1. Co firing and combustion in direct way
2. Anaerobic digestion
3. Gasification process

1.3.2.1 COFIRING AND COMBUSTION IN DIRECT WAY

The most popular technology used for biomass to power generation is direct combustion as in this the biomass material is used as raw material in boiler and then burnt. The steam generated is then fed to steam turbine which is further connected to the generator and thus electricity is produced. The process which is carried is as shown in figure 1.3.

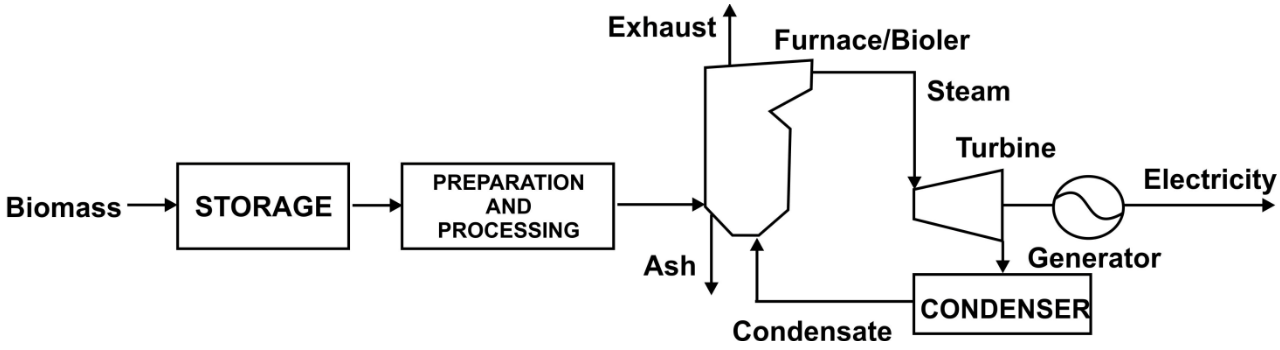


Fig 1.3 Direct combustion of biomass

The direct combustion of biomass is evolved in steps and the functions performed by the different units are -

Storage - The biomass material including the agricultural wastes like paddy husk, paddy straw, wheat husk and wheat straw etc are stored in storage unit where it is saved and is supplied as a fuel to carry the combustion process.

Preparation and processing unit - The biomass stored is then converted into simpler substances in the preparation and processing unit and is then fed to the boiler.

Boiler - Biomass is used as raw material or fuel in the boiler. The steam is generated due to the burning of raw material and is then fed to steam turbine.

Steam Turbine - The steam generated after the burning of raw material is sufficient to run the turbine. The steam energy is converted into electrical energy and thus the output is received from the turbine.

1.3.2.2 GASIFICATION

In gasification the biomass is converted into fuel in a closed vessel known as gasifier. Here the solid biomass can be converted into fuel and sand which surrounds the biomass has temperature of about 1500^0C which creates a very hot and oxygen ravenous environment. All these conditions break the biomass material and results in energy rich flammable gas. The process is shown in figure1.4.

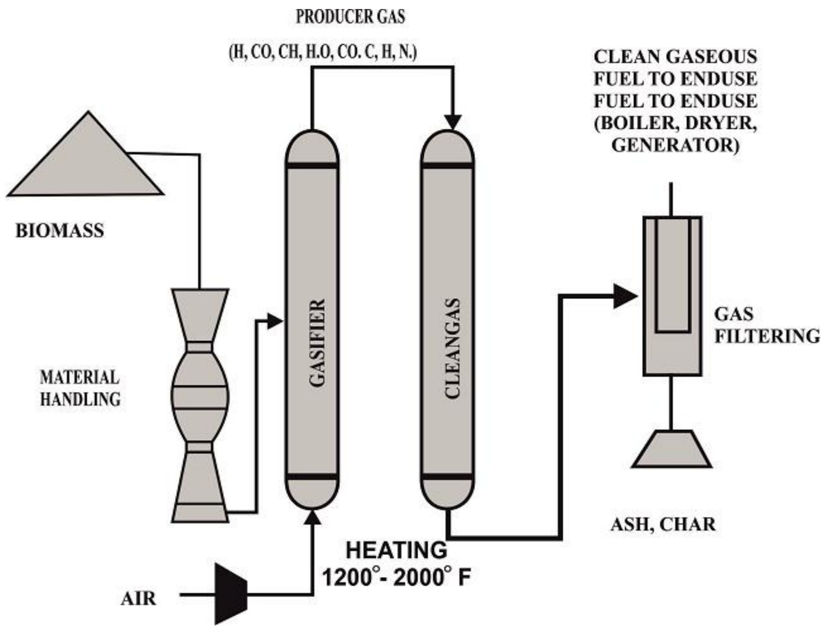


Fig 1.4 Gasification of biomass

The gasification of biomass is carried out in steps and the functions performed by different units are -

Material handling - In material handling unit, the raw material is supplied to the gasifier in continues manner and in small amounts.

Gasifier - Gasifier is a closed vessel in which the biomass is converted into fuel. The temperature of the gasifier is very high (1200^0C- 2000^0C) which results in the breakdown of the biomass material into energy rich flammable gases.

Gas filtering - The gases produced in gasifier contains hydrogen, carbon monoxide, carbon nitrogen etc that are flammable in nature. These gases are then filtered in the gas filtering unit and thus clean fuel is obtained from the gasification process.

1.3.2.3 ANAEROBIC DIGESTION

In the absence of oxygen, the animal wastes get digested to form biogas and this process is called anaerobic digestion and is shown in figure 1.5. For this process an airtight container is required in the presence of bacteria which help in digesting the animal wastes. The complex substances such as fat and protein are converted into simpler substances with the help of different types of bacteria and the biogas is further used in power generation through this combustion process. Nowadays, more advanced technologies are promoted to carry this process in an easy and fast manner. The process in anaerobic digestion is completed in three different stages as shown in figure 1.5.

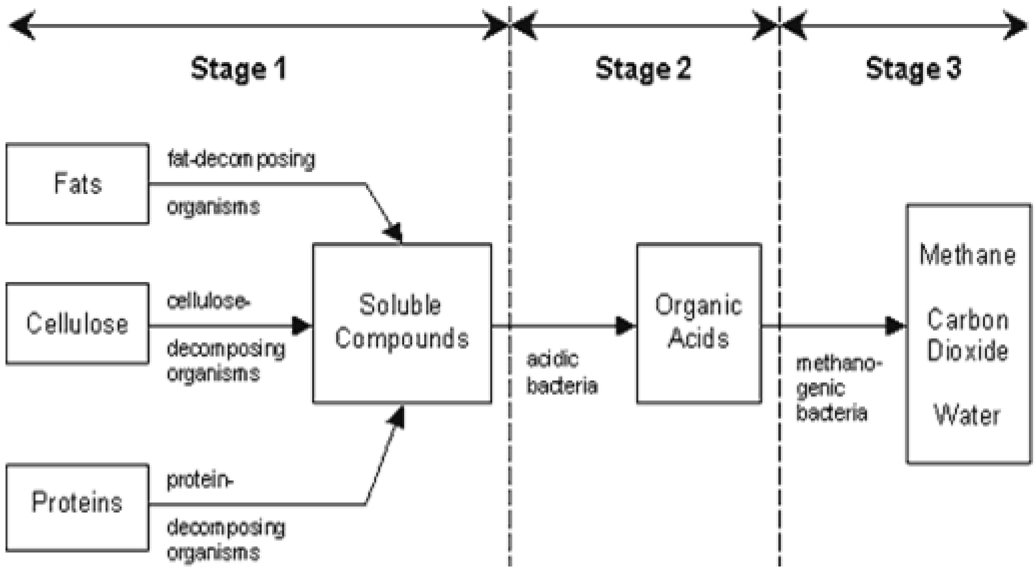


Fig 1.5 Anaerobic process of biomass

1.3.3 ADVANTAGES OF BIOMASS ENERGY

Biomass energy has many advantages. They are:-

1. It is a renewable, present in abundance and environment friendly.
2. It does not cause any harm to environment as no carbon dioxide is released.
3. It is a sustainable fuel.
4. It has very low ash content.
5. It contains energy contents which are more than any other sources of energy like coal etc.
6. It is free from environmental issues like acid rain, open pits, oil spills etc.

1.3.4 DISADVANTAGES OF BIOMASS ENERGY

Along with the advantages, biomass energy has also some disadvantages and they are:-

1. Biomass is an expensive source of energy.

2. Over collecting of wood can lead to destruction of forestry.

3. Combustion of biomass through direct process is a threat to environment.

4. Raw biomass is very difficult to store.

1.4 INTRODUCTION TO MHD GENERATOR

MHD generator is a magneto hydro dynamic generator which is based on the principle of Faraday's law which states that electric field is generated when a conductor moves in a magnetic field. The magnetic field intensity so developed is proportional to the **speed of the conductor** and **strength of the magnetic field**. Therefore it is a direct energy conversion system which converts the heat energy directly into electrical energy without any intermediate mechanical energy conversion. In this high electrical conductivity , speed of conducting medium as well as strong magnetic fields are vital to generate high power electrical energy without any transitional mechanical conversion.

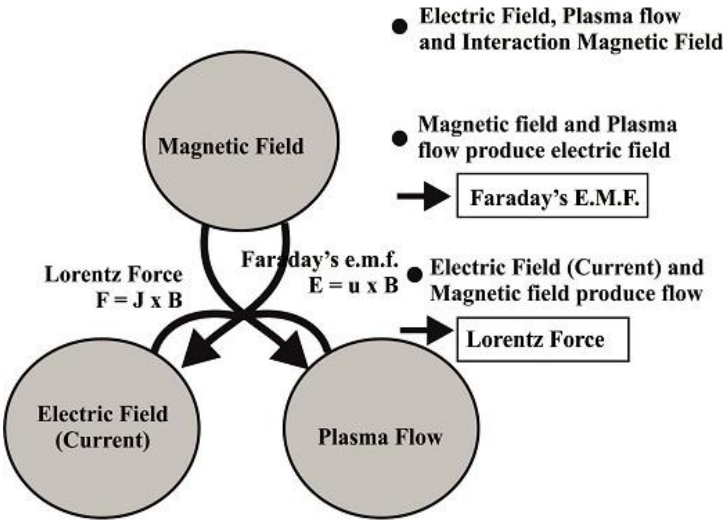


Fig 1.6 Correlation of magnetic and electric field with plasma flow

1.4.1 HISTORY OF MHD GENERATOR

Michael Faraday in 1832 firstly introduced the concept of MHD power generation during the original investigation on the process of electromagnetic induction (EMI). In 1907, Northrup designed the first MHD pump which converts the electrical energy of the current supplied into mechanical energy of the pumped fluid. MHD generator was invented by Karlovitz in 1910 by inverting the principle of MHD pump. Furthermore, research is done on power generation via these methods and many changes were observed with various outcomes which gave different results using different materials.

Search is on for better insulator and electrode materials which can withstand electrical, thermal, mechanical stresses.

1.4.2 POWER GENERATION PRINCIPLE

Faraday's Law of Electromagnetic Induction is the basic principle for the MHD power generation which defines that when a conductor moves in magnetic field, voltage is induced in it which results in the production of current.

The induced EMF is given by-

E_{ind}= U x M

Where U= velocity of conductor

M= Magnetic field intensity

The induced current is given by: -

J_{ind}= C x E_{ind}

Where C= electrical conductivity

As the name implies, magneto hydrodynamic generator is concerned with the flow of conducting fluid in the presence of electric and magnetic field. The conductor used in normal working generator has copper winding strips whereas the conductors in MHD generator are replaced with the hot moving (ionized) fluid called plasma which flows through the transverse magnetic field in a channel. Magnetic field and the electrode pair (at the side walls) are placed at right angle to the magnetic field which is then connected to external load through which the power is delivered. The function that is performed by brushes in normal generator is performed by the pair of electrodes in MHD generators. The output obtained from the MHD generators is DC and is converted to AC with the help of inverter as shown in figure 1.7.

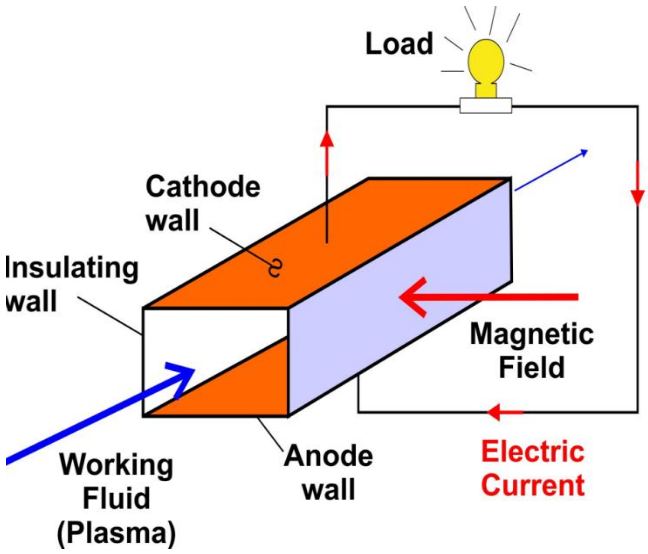


Fig 1.7 Working of MHD generator

1.4.3 MHD SYSTEM

For the power generation in MHD generators, high temperature gas source is required, that may be combustion gases of high temperature generated by burning of fossil fuels or a coolant from a nuclear reactor. Figure 1.8 shows the power generation through MHD system.

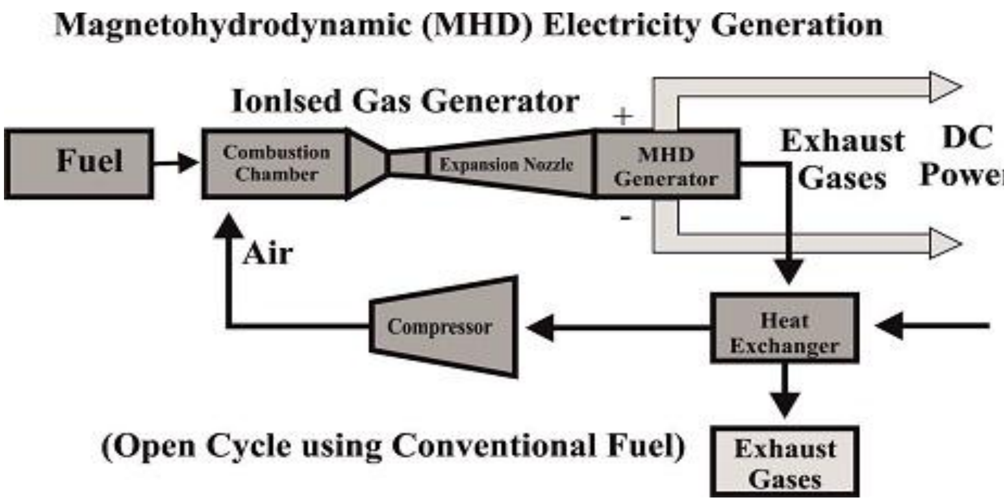


Fig 1.8 Power generation through MHD

In the expansion nozzle shown in figure 1.8 the pressure of the gas is reduced which in turn increases the speed of plasma by Bernoulli's Law and thus the power output is received. At the same time, the temperature of the plasma reduces due to the reduction in pressure value of gas which consequently increases the resistance of plasma. Different features of thermoelectric generator are:-

1.4.3.1 THE PLASMA

The whole MHD system depends on high electrical conductivity of plasma, therefore it is required to create and manage the conducting plasma. There are four states of matter - solid, liquid, gaseous and plasma state. Plasma is the state in which the atoms or molecules lose their electrons leaving positive charge on it. Therefore working fluids obtained from combustion are used as plasma in MHD generator.

Gas plasma - In order to achieve high conductivity, the gas must be ionized which is achieved when the electrons are removed from atoms or molecules resulting in positively charged plasma. Thus the current is induced in the circuit when the plasma flows through the magnetic field at a very high speed resulting in the inducement of current in the external electrical circuit.

Methods to ionize the gas – Ionization can be done by heating the gas with X-rays or Gamma rays. It can also be possible by using the coolant gases like helium, carbon dioxide. This will act as plasma in MHD power generation. Seeding materials are also added along with them so as to increase the electrical conductivity and ionization of plasma which includes- Potassium carbonate or Cesium.

Containment - As the plasma temperature is usually over 1000^{o}C, therefore the ducts containing the plasma need to be constructed from non-conducting materials so that they must be capable of withstanding the high temperatures and stresses. In figure 1.9 the graph shows the change in conductivity with ionization. It is noted that with fairly low degree of ionization of about 1%, conductivity can be achieved up to 90%.

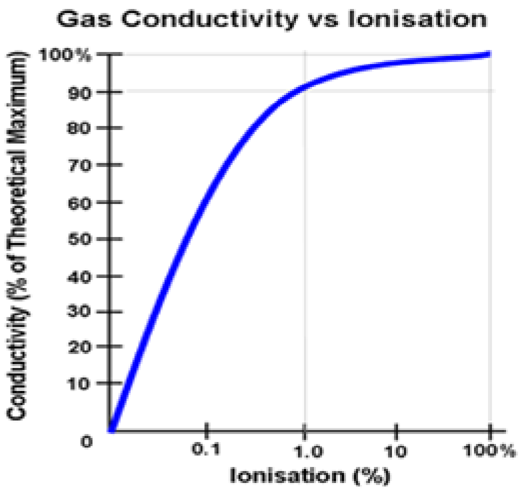


Fig 1.9 Graph showing the change in conductivity with ionization

1.4.3.2 THE FARADAY CURRENT

Powerful electromagnets produces the magnetic field through which the plasma flows, and the electrodes are placed perpendicular to this magnetic field on the opposite sides of plasma. Thus the output is generated at this point and this will result in the flow of current across the plasma between the electrodes; known as Faraday Current and is the main electrical output of MHD generator.

1.4.3.3 THE HALL EFFECT CURRENT

The current produced when the output current flows across the plasma duct reacts with the applied magnetic field; that current is known as Hall Effect Current. Moreover, Faraday Current and Hall Effect Current are perpendicular to each other. The vector sum of both the Faraday current and Hall current gives the total current.

Different configurations of electrodes are done so as to increase the overall efficiency of MHD power generation. The best and most common method is to split the electrode pair into series of segments placed parallel insulated from each other. The segmented electrode pairs are connected in series to get high voltage output and are skewed at slight angle instead of placing directly opposite to each other. The aim of skewing the electrode pairs is to make the vector sum of Faraday and Hall Effect current in series with the electrode pair to get the maximum energy which is to be extracted from the plasma. Figure 1.10 shows the MHD current flow with segmented electrodes.

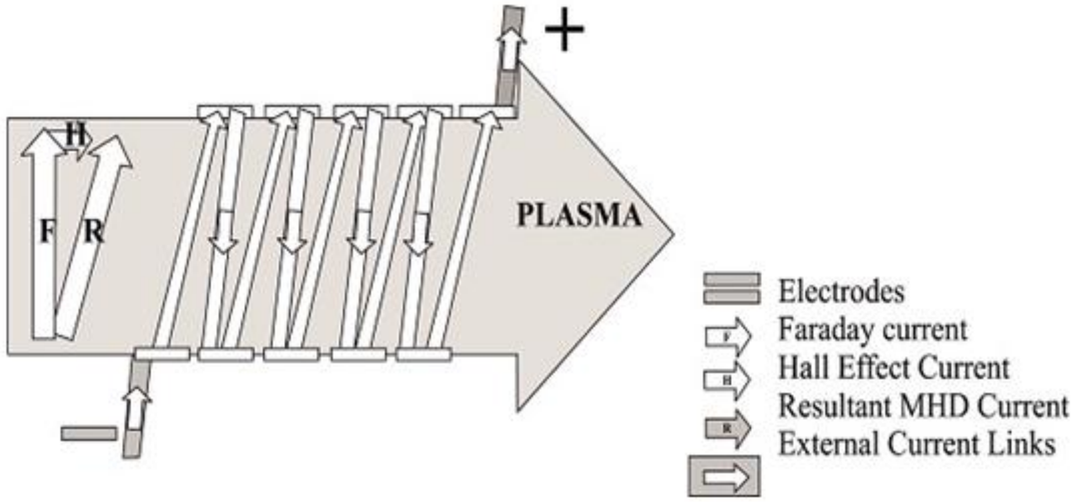


Fig 1.10 MHD current flow with segmented electrodes

1.4.3.4 POWER OUTPUT

The output from MHD generator is directly proportional to the rate of flow of ionized plasma and the cross sectional area. The output is DC in nature which is then converted into alternating current with the help of inverters.

1.4.3.5 EFFICIENCY

The conversion efficiency of MHD system is 50% higher as compared to other power generating units. Moreover, with the improvements in technology, the efficiencies of MHD system is expected to be increased to 60-65%.

1.4.3.6 DESIGN OF MHD GENERATOR

The size and weight of MHD generator using an outer source may exceed from generator itself therefore MHD generator so selected must have permanent magnets which do not require any external source. Pulsed MHD generator is widely used to produce electrical power pulse generation and in order to produce high velocity plasma; pulse is ignited by an independent high pressure and high temperature. It is a conventional type of generator and the pulse produced in this is 15 to 500 MW. MHD channel has electrical output of 510 MW and the channel dimensions are of length 4.5m, input area of 0.9 x 1.0m and output area of 1.6 x 1.0m. The working plasma contains about 40% of liquid particles of aluminum oxide (Al_2O_3) and treats this as liquid particles.

Hence the output of generator can be improved by:-

1. Selecting a load matching to generator characteristics.
2. Employing self excitation technique.
3. Increasing the speed of plasma.
4. Changing shapes and types of permanent magnets placed in the generator.

1.4.4 TYPES OF MHD SYSTEM

There are two different types of MHD system. They are:-

1. Open cycle system
2. Closed cycle system
    a) Seeded inert gas system
    b) Liquid metal system

1.4.4.1 OPEN CYCLE SYSTEM

In an open cycle system the fuel used can be coal or oil which is burnt in the combustor or combustion tank. The hot gases released by burning of fuel are then fed to MHD generator along with the seeding material (Cesium or Potassium) so as to increase the electrical conductivity of the gas. The most commonly used seeding material is Potassium Carbonate. The compressed air is required in the combustion chamber so as to burn the gases in order to maintain high temperatures of at least 1100^0C.

Then the hot pressurized fluid in the combustion chamber will flow through a convergent divergent nozzle in which the pressure of the gas is reduced and due to this the speed of the plasma entering the generator is increased by Bernoulli's Law. Therefore the gas enters in the generator with high velocity. The hot gas expands in the generator due to the powerful magnets present in it and during the movement of gas in the generator the +ve and -ve ions move to the electrodes resulting in the production of current in the direction of working fluid and thus the output is received. Figure 1.11 shows the block diagram of open cycle MHD system.

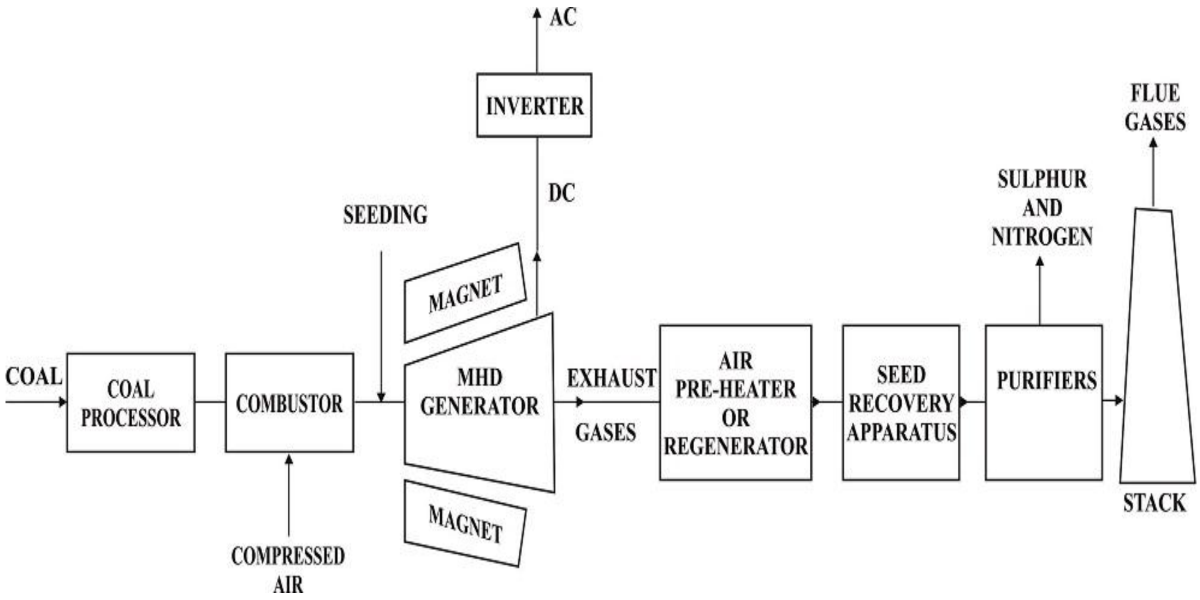


Fig 1.11 Open cycle MHD system

1.4.4.2 CLOSED CYCLE SYSTEM

Working fluid, after the power generation is recycled to the heat sources and thus the cycle is completed. Therefore, it is known as closed cycle system. Any chemical inert gas can be considered as carrier. In closed cycle system, liquid carrier is used with liquid material conductor. The working fluid is heated in the combustion chambers using heat exchangers and is circulated in closed loop. Argon or Helium can be used as working fluid with Cesium as seeding material. Figure 1.12 shows the closed cycle system.

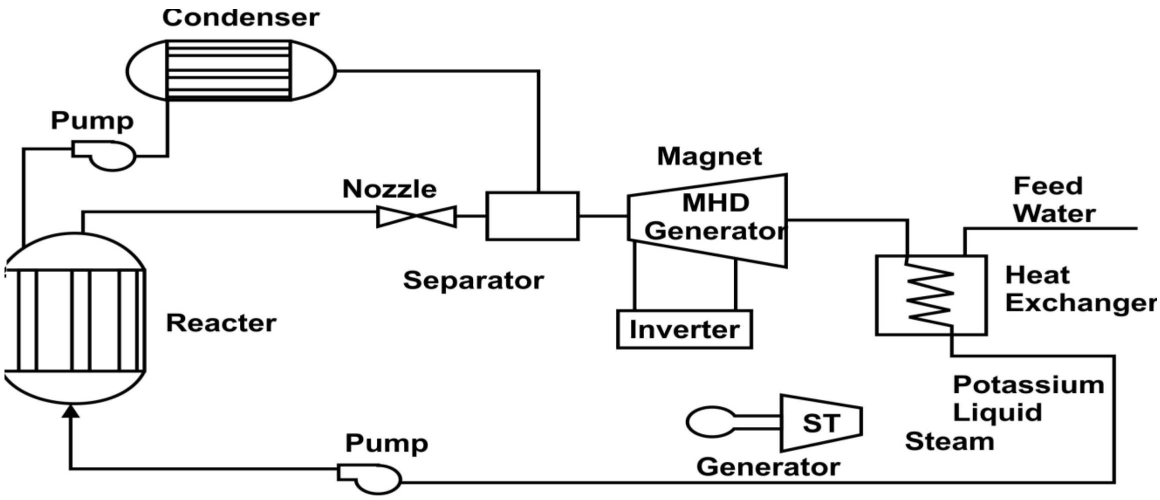


Fig 1.12 Closed Cycle

1. Seeded inert gas system

Heat is supplied by the heat source at the constant pressure in seeded inert gas closed system where the gas is compressed and this Seeded inert gas system is a closed system; in which the gas is compressed and this compressed gas expands in the MHD generator resulting in decrease in the temperature and pressure of gas. The gas is then cooled down with the help of cooler when it is leaving generator and this process is known as rejection state of the cycle. This gas is then recompressed and returned for reheating. The cycle is therefore referred to as closed and hence the name is closed cycle system. Coal is used as fuel or raw material in the combustor and the products of combustion process are passed into the atmosphere after passing into the purifier. Flue gases are utilized to preheat the incoming combustion air. As a result the hot argon gases along with the seeding material (Cesium) results in the working fluid which is then fed to MHD generator at a very high speed.

2. Liquid metal system

In this closed system the electrical conductivity is provided by liquid metal and is known as liquid metal MHD system. Liquid metal acts as working fluid and gets heated through the passage inside the combustion chamber. The liquid metal also gets pressurized in the heat exchanger during the passage and thus the hot gases are passed into MHD generator along with the seeding material and in this hot sodium are used. This is the working fluid and is fed to the generator through nozzles. The main function of the carrier wave is to provide high speed to the electrical conductor. The liquid metal is then separated from carrier gas after passing through the generator. The temperature of the working fluid is usually around 800^0C. At the lower operating temperature the maximum thermal efficiency also gets lowered. Liquid Lithium can also be used as electrical conductor but it is expensive than sodium. Therefore, sodium is better to use.

1.4.5 DIFFERENCE BETWEEN OPEN AND CLOSED CYCLE SYSTEM

Open and closed cycle systems are different from each other and in Table 1.3 the comparison between both the cycle systems is shown.

Table 1.3 Comparison between open and closed cycle system

OPEN CYCLE SYSTEM	CLOSED CYCLE SYSTEM
1. After power generation, working fluid is discharged to the atmosphere.	1. After power generation, working fluid is recycled to heat sources and is reused.
2. The working fluid used in open cycle is the combustion products.	2. The working fluid used in closed cycle system can be Helium or Argon.
3. Temperature required here is 2300^0C.	3. Temperature required here is 540^0C.
4. It is in developed form.	4. It is less developed.
5. The end products are not recycled and hence the name.	5. The end products are recycled and are reused.
6. Seeding material is not required.	6. Seeding material is required.

1.4.6 ADVANTAGES OF MHD GENERATOR

MHD generator has many advantages and are listed below-

1. The efficiency of MHD system is 50% higher than power generating plants and with the improvements in technology, the efficiency of the MHD system can be increased to 60-65%.

2. The power generated is very large.

3. It is more reliable because of the absence of moving parts.

4. The size of the plant is smaller than all usual systems.

5. It gives pollution free generation.

6. Operating costs of MHD generation is around 20% which is less than usual systems.

7. The fuel is fully utilized in this generation and leads to less fuel consumption.

8. Due to direct conversion of heat into electricity, turbine gets eliminated which in turn reduces the losses of energy.

9. It is used for peak power generations or in emergency conditions.

1.5 INTRODUCTION TO THERMOELECTRIC GENERATOR

Thermoelectric generator (TEG) is basically a solid state device in which heat energy is directly converted into electrical energy. It is normally known as Seeback generator that works on the principle of converting heat or temperature differences directly into electrical energy. Free charge carriers which can be electrons or holes in the material, are driven to cold end as the heat flows from hot to cold junction. This will lead to the voltage production of the voltage and its value is directly proportional to the temperature between two elements via Seeback coefficient. The voltage produced is the result of connecting an electron conducting (i.e. n-type) and the hole conducting (i.e. p-type) in series. A good Seeback material has Seeback coefficient between 100 to 300 micro volts per Kelvin.

1.5.1 SCHEMATIC DIAGRAM OF SINGLE TEG

Thermocouple or single TEG is formed by connecting the n-type and p-type semiconductor elements in series and the two sides of thermocouple are maintained at different temperatures and this can be done by giving the continuous heat supply at one side and connecting the heat sinks at another side. Consequently, one side will become hot and the other side will become cold. Due to this temperature difference the charge carries begin to move in n-type and p-type materials resulting in the production of voltage at the load i.e. the output is received. Figure 1.13 shows the schematic diagram of thermoelectric generator.

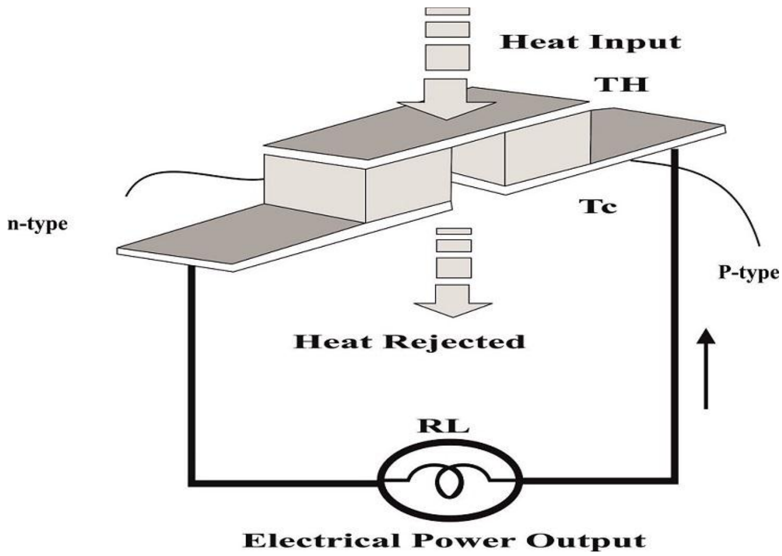


Fig-1.13 Basic diagram of thermoelectric generator

1.5.2 WORKING PRINCIPLE OF TEG

It is basically based on the effect known as Seeback effect discovered by Thomas Seeback in 1821 who observed that electric charge flows when one junction of two dissimilar metals; is heated and the other junction is cooled. The two semiconductors are connected in series and thermally in parallel so as to increase its efficiency. The junctions that are used to connect the hot and cold plate are made up of highly conducting metal like copper strips. The electrons will flow from hot junction to cold junction as electrons present on the hot side of plate are more energized that the electrons at the cold side.

If the circuit is completed, electricity will flow continuously and the output will be received in a continuous manner.

1.5.3 PERFORMANCE OF TEG

The performance of TEG is based on many features which are listed below-

Thermal conductivity – The ability of the material to conduct the heat is known as thermal conductivity. Therefore the materials selected for generator must have high thermal conductivity so as to perform better and increase efficiency. (S.I. unit- W/ m-K)

Thermal expansion coefficient - It is the amount of change in the size of material with change in temperature. So TEG must have high thermal expansion coefficient. (S.I. unit- ^{o}C or K)

Specific heat - It is defined as the heat capacity per unit mass of the substance. (S.I. unit- J/ K)

Resistivity - It is the feature which tells about the strength of a material opposing the flow of current. (S .I. unit -Ω m).

Seeback coefficient – The amount of induced thermoelectric voltage in reaction to temperature is measured by the special feature known as Seeback coefficient. Since the voltage induced is directly proportional to Seeback coefficient. So for better performance of TEG the Seeback coefficient must be high because as a result the output will be more. A good Seeback material must have Seeback coefficient between 100 to 300 micro volts per Kelvin.

If Seeback coefficient is represented by 'S' and temperature difference is by ΔT between the two ends of material, then the thermo power of a material is given by :-

$$S = \frac{\Delta V}{\Delta T}$$

If the result is positive; then it indicates the flow of holes and if the result is negative; then it indicates the flow of electrons.

Figure of merit Z- For thermoelectric devices, Z (figure of merit) is defined as the expression which represents the efficiency of the device or performance of the device.

$$Z = \frac{\Theta S}{\mu}$$

Where

Θ = electrical conductivity

μ = thermal conductivity

S = Seeback coefficient

The dimensionless figure of merit ZT can be calculated by multiplying the figure Z with the average temperature T

Where, $T = \frac{(T_1+T_2)}{2}$

Therefore, higher the figure of ZT; higher will be the efficiency of material or vice-versa with a condition that the two dissimilar materials have similar Z.

Efficiency: - It is defined as the performance or the amount of power generated. It is represented by 'η'. Also more the value of efficiency better will be the performance of generator.

$$\eta = \frac{\text{energy provided to the load}}{\text{heat energy absorbed at hot junction}}$$

1.5.4 THERMOELECTRIC MATERIALS

The materials which show the thermoelectric effect (phenomena by which either a temperature difference creates an electrical potential or vice-versa) in a strong and suitable form are known as thermoelectric materials. Thermoelectric materials have wide range of solid compounds which are differentiated by their property of converting the heat energy into electrical energy. The most popularly used thermoelectric material is bismuth telluride (Bi_2Te_3). The usefulness of a material in thermoelectric systems is determined by low thermal conductivity, high electrical conductivity and seeback coefficient. For the same semiconductors are best suited for thermoelectric devices due to their band structure and are good in electrical conductivity.

Also, ZT (figure of merit) is the main criteria for selecting the thermoelectric material and is dependent on the operating temperature of module. Most commonly used thermoelectric materials are antimony and bismuth telluride at room temperature i.e. 300 K, lead telluride at temperature i.e. 650 K and silicon germanium alloys at high temperature of about 1000 K.

In order to have advanced thermoelectric materials, decoupling of (electrical conductivity), **κ**(thermal conductivity) and S(Seeback coefficient) is required as they are interdependent on each other. It can be achieved by reducing the lattice contribution to thermal conductivity with the help of Nano structuring method by which the materials carrying photons are scattered by introducing boundaries at Nano scale. Consequently, by Nano structuring value of ZT is increased to 1.5 from 1, increasing the efficiency of thermoelectric materials. Figure 1.14 shows the improved performance of thermoelectric material with the help of Nano structuring.

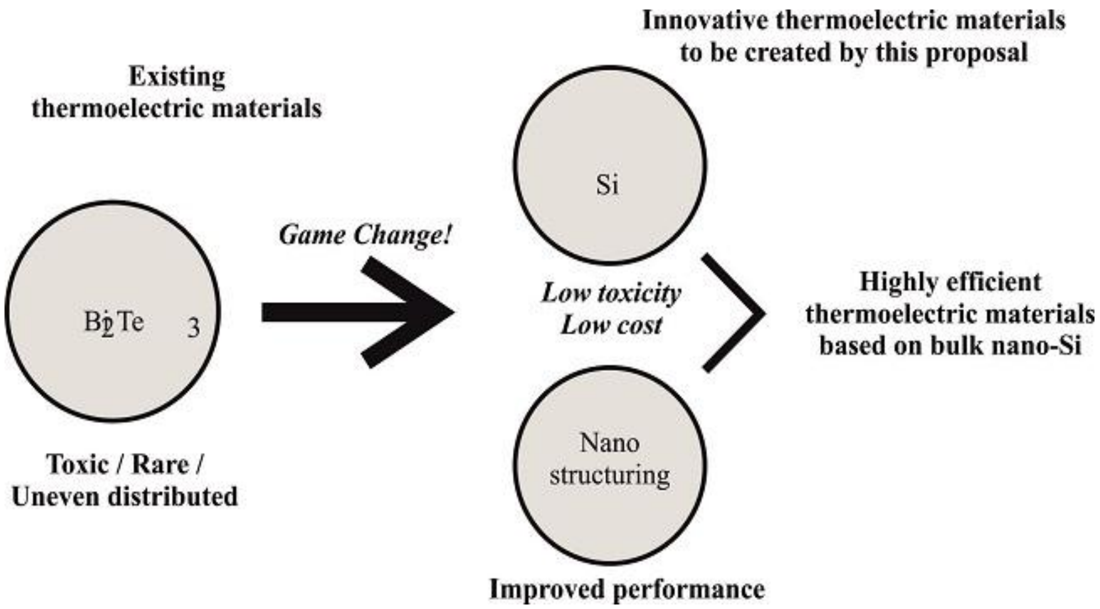


Fig 1.14 Nano structuring of thermoelectric material

Synthesis of thermoelectric materials is done by metallurgical techniques like Powder metallurgy, Nano structuring etc.

It is essential to have materials in pure form as the impurities can have negative effect on the conductivity and concentration of charge carriers.

The common materials used in thermoelectric generator are given in the Table 1.4.

Table 1.4 Different Thermoelectric materials

MATERIAL	DESCRIPTION	MOLECULAR FORMULA
Antimony selenide	Antimony(III) selenide has 99.99% trace metals	Sb_2Se_3
Antimony telluride	Antimony(III) telluride in powdered form	Sb_2Te_3
Bismuth selenide	Bismuth selenide in granular form or melted	Bi_2Se_3
Bismuth selenide	Bismuth (III) selenide	Bi_2Se_3
Bismuth telluride	Bismuth (III) telluride in powdered form	Bi_2Te_3
Lead selenide	Lead (II) selenide in granular form	PbSe
Lead telluride	Lead (II) telluride in 99.9% on trace metal basis	Ag_2Te

1.5.5ADVANTAGES OF TEG

The advantages of thermoelectric generator are-

1. TEG is very reliable as it can operate for more than $1*10^5$ hours in continuous manner.

2. It operates silently because of the absence of moving parts, thus resulting in no noise pollution.

3. It is quite simple, compact and safe in operation.

4. It can operate at prominent temperatures and requires less maintenance.

5. The size of generator is small or almost weightless.

6. It is suitable for small scale power applications.

1.6 HYBRID CONCEPT

Due to modernization, the power demand is increasing day by day resulting in a wide gap between supply and power demands. Efforts may be oriented towards the search of new sources of energy and has led to the growth of other non conventional methods using renewable sources. As a result, rush to biomass systems have been promoted around the globe at a very large scale as biomass is used as a raw material either in primary or secondary processing units. Nevertheless, plants using biomass as raw material are promoting problems like carbon dioxide emissions and methane gas emission which are threat to earth's ozone layer. High ash content and heat release to environment are the harmful effects of biomass plant. In order to get optimal generation conditions, cogeneration of biomass plant is done so as to provide clean energy to environment.

For this reason, biomass cogeneration is done using MHD generator, thermoelectric generator so as to increase the reliability and efficiency of the system. Normally the efficiency of boiler is 25-35% but by using the cogeneration, efficiency has increased to 65-85% because flue gases obtained from burning of raw material are cycled again to boiler after passing through MHD and TEG generator. As a result the boiler will need less energy to increase its internal temperature thereby increasing the efficiency of boiler.

The flue gases obtained after burning the fuel in boiler is fed to TEG, from where they move to MHD generator. The seeding material is added as the flue gases enter the MHD generator so as to increase the electrical conductivity of the gas. Now, again the flue gases are fed to boiler and consequently the cycle is completed.

The output from TEG is utilized by the cogeneration plant itself, so as to fulfill power requirements of the plant such as in cooling systems, fans etc. leading to less power consumption.

The other two outputs i.e. from turbine and MHD generator are fed to the grid so as to meet the power demands.

1.6.1 BLOCK DIAGRAM OF HYBRID PLANT

The block diagram of the hybrid or the cogeneration plant is shown in figure1.15.

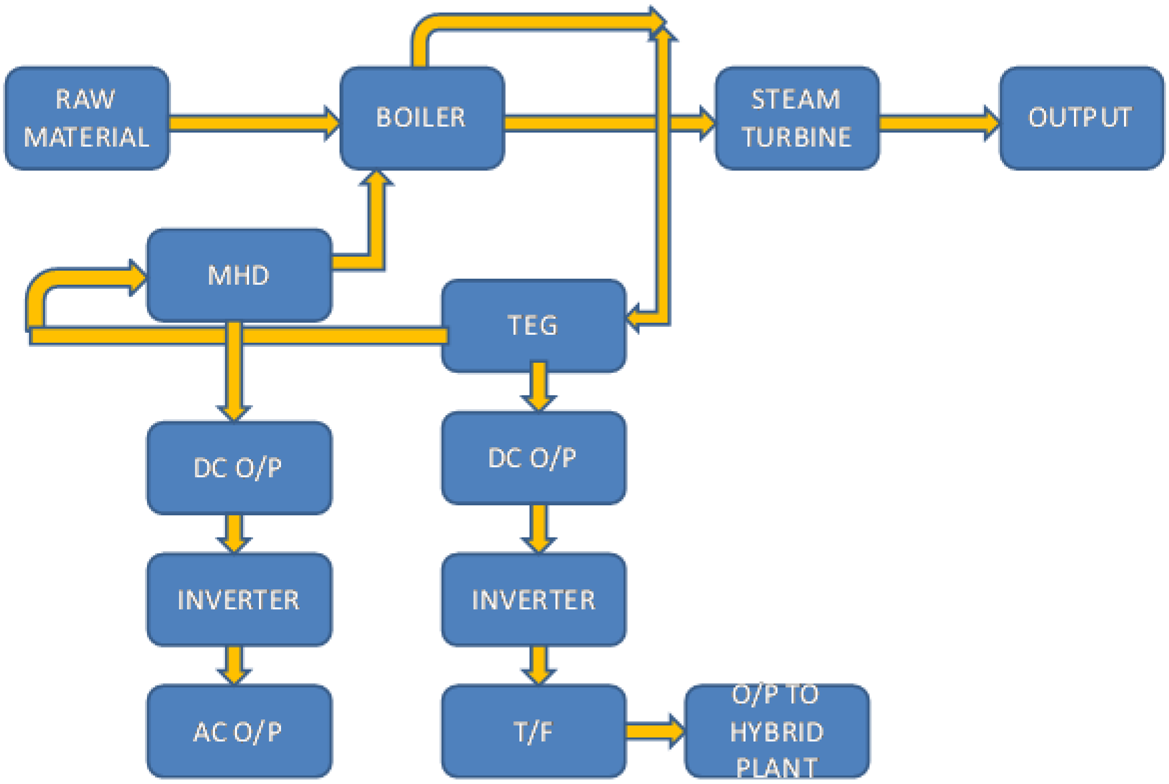


Fig 1.15 Block diagram of hybrid plant

1.6.2 WORKING OF HYBRID PLANT

The block diagram of hybrid plant is shown in figure 1.15 in which the raw material or biomass is burned in the boiler. The steam generated through this combustion process is used to run the steam turbine and the output is received from the generator. This output is further fed to the grid for power supplies. In addition, the flue gases which are obtained by burning of raw material in boiler are fed to TEG and MHD generator.

In MHD generator, the flue gases along with seeding material i.e. Cesium or Potassium are added to increase the electrical conductivity of the gas and with the Faraday's law the output is received. In MHD generator hot conductive plasma is used as moving conductor.

As a result, three outputs are obtained from the cogeneration plant; i.e. from the steam turbine, MHD generator and thermoelectric generator which results in increasing the reliability of the plant. The output from TEG is utilized by the plant itself for its power requirement such as in cooling systems, fans etc. Thus hybrid system has many advantages and future scope as it only depends on renewable resources which can lead to boost in power development.

1.6.3 ADVANTAGES OF HYBRID PLANT

The hybrid plant has many advantages and they are listed as under-

1. The conversion efficiency of MHD generator is i.e. 50% higher than the normal power generating plants and with the improved technologies the efficiency can be increased to 60-70%.
2. Power requirements of the plant are fed itself by TEG which helps in power saving.
3. Hybrid system is more reliable and efficient as if the working of one unit will be hindered the supply will remain continues from the second unit resulting in continues power supply.
4. Power generation will be in large amounts because three outputs are received out of which two are fed to power grid.
5. The hybrid plant helps in reducing the global warming and promoting the clean environment.
6. The cogeneration system can be set in almost every village as the biomass waste will be present in abundance. Thus the rural areas will be supplied with continues supply. It is estimated that about 5000 villages in Punjab can be benefited with cogeneration systems and can have 24 hours power supply.
7. The cost per unit of energy generated is also reduced.
8. There will be no problem of grid failure and transmission losses.

CHAPTER-2

LITERATURE REVIEW

Viswalingam Dr. K. and Solomon Dr. F. (2014) presented the features of biomass as power generation. Biomass can be used as an alternative source of energy and the gas obtained from biomass is biogas. The paper reviewed the economic, social and cultural impacts of biogas technology and the use of biomass in present as well in future. Biomass is used as raw material either in primary or secondary processing units. Results recommend that biogas technology must be encouraged, promoted, invested and implemented especially in rural areas. The basic form of biomass includes virgin wood, energy crops, animal wastes and crop residues and also collected from agro- industrial processing by-products such as bagasse, sawdust, oil palm residues and wood off cuts. Therefore using the wastes and residues has lead to the conversion technologies treating them as raw material resulting in fulfilling the increasing demands of energy. Further biogas utilization, its uses and applications were analyzed.

Mishra et al. (2013) proved the factors promoting the use of renewable sources of energy in India which includes the increasing the demands of electricity, increases in the prices of fuel etc. Due to the limited presence of resources like coal, petroleum and natural gas, the use of renewable resources has grown to large extent and promoted various technologies using these resources. Till now energy from these resources has contributed about 12% of the total power generation. The paper promotes the cogeneration plant using solar energy and biomass energy which provides enough energy to meet the power demands at nearby villages. It is possible to build the hybrid system where extension of grid is considered uneconomical.

David B. Dorucher & Bill power (2012) had done a case study of one sawmill in the pacific North US that pursued a bold proposal to increase the scale of produced products, and also to generate the electrical energy in large amount. From several years there had been limited availability of wood fiber, also the supply and demand continue to struggle to find equilibrium.

The paper focuses on the electrical systems or other changes added to the site that enabled the mill to produce enough energy to fulfill the growing demands. The wood waste from sawmill was taken as biomass fuel source so as to reduce the operating costs of plant. Hence to overcome this problem biomass cogeneration was done and as a result, site enabled the mill to produce enough energy to fulfill the demands while reducing the greenhouse gas emissions and also increasing the efficiency of plant.

Overend Ralph P. (2010) proposed the details of biomass availability for bio power applications. Biomass is a perfect fuel for Combined Heat and Power (CHP) applications as it is highly publically acceptable. In biomass power plant, as the plant size increases, the capital cost MW and operation and maintenance cost per MWH decreases; on the other hand as the plant size increases, fuel cost per MWH also increases.

Sakamoto and Harada (2008) have represented the development or changes carried out in MHD generator. It is demonstrated that the maximum electric power output of 510 MW is received when the MHD generator channel is of 4.5m. Many changes were carried out in combustion plasma (burning fuel in generator) and then output is analyzed. Different seeding materials are added to the plasma so as to increase the electrical conductivity of gas and the results were analyzed. In the paper many development in current density distribution, development of 3D flow and power generated is also present in the paper. The model deals with the electrical fields in MHD generation and interaction between the flows of plasma. The study was done to analyze the performance in the MHD generator.

Ahn Jae Woon , Lee Jaimin and Choi Jin Soo (2008) had studied in the paper about the effect of load resistance and inductance on performance of MHD generator. MHD generator was so selected which do not require any external energy source and have permanent magnets. Then the design features of generator were varied and with different configurations, different outputs are viewed and the condition at which maximum power output is analyzed.

Along with the permanent magnets, copper electrodes are used and to measure the velocity of ionization of gas. Further the load resistance is also varied in the range from 2.5 to 120 mΩ and the value of the inductance is varied from 0.20 to 36 μH. After the tests were performed, the result concluded was that when the inductance or load resistance is increased, the current is decreased but the generated voltage will remain constant (approximately). It is also concluded that the power output of MHD generator is improved by increasing the speed of plasma, changing shapes and types of permanent magnets as well as electrodes, selecting the load matching with the generator characteristics.

Kobayashi Hiromichi and Satou Yukimasa (2008) proposed the performance of disk MHD generator in which frozen inert gas is used as plasma and the results are examined numerically. It was proved that argon is more widely used to have control on inlet ionization degree instead of helium. The reason is that argon has high inlet electron number density than helium and also the load resistance of argon is less than helium.

Kobayashi Hiromichi and Okuno Yoshihiro (2000) have represented the feasibility of MHD generator in which frozen inert gas is used as plasma and when helium is pre ionized, frozen inert gas plasma is produced. Any alkali metal is seeded at the inlet to the generator so as to increase the ionization and conductivity. Many experiments were performed to study the feasibility of MHD using inert gas plasma obtained by pre ionizing the inert gas and also the efficiency of the plant can be increased as conventional seeded plasma MHD generator. It was concluded that in the strong and stable magnetic field the frozen inlet gas plasma also remains constant.

The ionization degree is also maintained constant by which the performance of generator was improved. Also by using the frozen inert gas as plasma will increase the efficiency of the system.

Kim M.S. Kim and Kim Y.J. (2013) reported in the paper that thermoelectric generator with a phase change material (PCM) provides a function of heat energy storage. The output is received due to the temperature difference of both the elements i.e. generator produces electrical energy due to difference in temperature between hot and cold junction. The conversion of energy and the efficiency of TEGs decrease rapidly when the heat source is eliminated from the hot junction. The thermocouples are joined together in series so as to form thermoelectric generator and polymer substrate is embedded with PCM. The energy dissipated from a heat source is stored by thermoelectric generator. The plus point of thermoelectric generator is that it will maintain energy conversion efficiency continuously even after the removal of heat source. So it is concluded that the energy conversion of TEG decreases rapidly when heat source is removed and to maintain the energy conversion efficiency after heat source removal; it is required to embed PCM in TEG.

Jovanovic Velimir and Elsner Nobert B. (2006) in the paper designed a prototype thermoelectric generator which utilizes the waste heat from heat sources to provide power to sensors used in navy ship machinery. Thermoelectric generator used in ships are fabricated by Quantum-Well thin films and thus with respect to the utilization of power; they are also used to generate electricity directly without using the moving parts. They are basically nano-structured multi-layer film. As the power is extracted from environmental sources like wind, tides, shocks, heat etc which replace the batteries as electrical power sources. Hence the power supplies can be done through utilizing the heat transfer between the ship board waste heat sources which results in generating the electricity and increasing the efficiency and performance of TEG.

Li Yida , Singh Navab and Lee Sung Joo (2012) studied in the paper about the TEG which was filled with polyimide and was fabricated by two orders to improve the performance in generated power output by filling the counterparts with silicon oxide.

Their best ability is to power up to microwatt which can be possible by increasing the efficiency of the plant using the silicon oxide.

Improved form of thermoelectric generator is used by fabricating it with polyimide in their side parts. TEG utilizes the waste heat into electricity and thus helps in conserving the energy. Many changes were made in the designing of thermoelectric generator which led to the improved performance of generator. Along with this further optimization is done in areas like doping characteristics, their metallization, changing the length etc to improve their performance and efficiency.

CHAPTER 3

PROBLEM FORMULATION

Energy plays a very important role in everyday life and due to modernization the demand is increasing day by day resulting in wide gap between supply and power demands. Efforts can be oriented towards the search of alternate sources of energy. Therefore the biomass systems have been promoted all around the world at a large scale but side by side it is also encouraging problems like carbon dioxide emissions and methane gas emissions which are threat to Earth's ozone layer. High ash content and heat release to the environment are also the major harmful effects of the biomass plant. In order to get optimal generation conditions, cogeneration of biomass plant can be done so as to provide clean environment. For this reason, biomass cogeneration is done using MHD generator and TEG so as to increase the efficiency and reliability of the system. Normally the efficiency of boiler is 30-35% but by using the cogeneration efficiency has increased to 65-85% which is high enough. Therefore, combined power is generally promoted to meet the growing demands and to provide clean environment.

3.1 SIGNIFICANCE OF PROPOSED WORK

Biomass has a lot of scope in villages due to the availability of waste material as fuel. So the main reason of using the hybrid system is:-

1. About 5000 villages in Punjab can be benefited and can have 24 hours power supply

2. The non conventional energy sources like biomass, biogas is available in abundance and thus there is a vast scope for hybrid plant especially in Punjab.

3. The cost per unit of energy generated is reduced due to cogeneration system i.e. about Rs.3.00 to Rs.4.00.

4. Payback period of such plants is very less.

5. There is no problem of grid failure and transmission losses.

3.2 OBJECTIVES

The main objectives of cogeneration plant are:

1. To compare all the required data like input, output, efficiency, and cost per unit etc of both the standalone biomass plant and hybrid plant.

2. To reduce the cost per unit of energy generated by the hybrid plant so that the efficiency of the plant increases and consequently use of cogeneration plant is a better way to meet the growing demands of power.

3. The analysis of the plant is done with the help of MATLAB and as result; model is made in MATLAB-simulink to have the required results of hybrid plant.

3.3 METHODOLOGY

The steps followed for completing the proposed work are as under-

1. Collection of data (Location of area, total land area, area under crops, residue to production ratio, energy consumption, agri-residue output) is done from agricultural office, Dehlon.

2. Cost estimations (Subsidies by government and private bodies, generation cost and from net) are noted down.

3.Testing of the fuels for obtaining its combustion related property i.e. calorific value with the help of Bomb Calorimeter.

4. On the basis of available data; potential of the plant, cost per unit of power generated by the hybrid and standalone plant is calculated.

5. Specifications of MHD generator and thermoelectric generator are so selected to be matching with the capacity of biomass plant; so as to check the feasibility of the working of cogeneration system.

6. Simulink models of standalone and hybrid plants are made with the help of MATLAB.

7. The output, efficiency and cost per unit of both the plants are compared in tabular form.

CHAPTER-4

PRESENT WORK

Cogeneration of biomass plant with the help of MHD generator and thermoelectric generator is the main proposed work. The data is collected from the nearby villages of block Dehlon, Punjab and the specifications of MHD generator and thermoelectric generator are to be matching with the capacity of biomass plant; so that the cogeneration system will work out. The proposed standalone and hybrid model are completed using MATLAB and the outputs are discussed. With the output; cost per unit of both the plants is calculated. Further both plants are compared on the basis of parameters (input, output, cost per unit, efficiency) in tabular form.

Before proceeding to the designing of power plant, potential and electrical load of block Dehlon, Punjab is calculated such that the proposed plant will fulfill the growing power demands. Modifications will have to be considered for the required output.

4.1 ESSENTIAL POINTS FOR SETTING UP THE PLANT

The block diagram of the proposed system is shown in the figure 1.16. For efficient and successful working of the plant, following points need to be focused:-

1. Availability of raw material (Biomass) - The area where the plant is proposed to be set up must have sufficient presence of biomass or raw material for the working of the plant so that no problem may occur in future regarding the amount of raw material availability. It is the basic feature required for the working of plant. Moreover, it is easy to set biomass plants in villages as raw material is present in abundance.

2. Availability of area - The plant set up needs large area for its working and for that spacious area is required for setting up a plant.

3. Waste disposal - The area for disposing the waste must be present so that it may not cause any pollution and harm the environment. Proper methods need to be carried out for disposing of the waste.

4. Availability of labor - Biomass plant can be easily set up in villages as waste material is present in abundance. Local villagers can work in the plant, thus promoting employment

4.2 CASE DESIGNING

For the designing of biomass plant, amount of waste material, load demand and potential of agricultural residues are calculated so that proposed plant will fulfill the growing power demands.

4.2.1 CIRCLES OF DEHLON BLOCK

There are total 70 villages in Dehlon Block which are further divided into 6 circles. Total agricultural land of the block is 55500 acre. The information is collected from Dehlon Agricultural Officer. Table 4.1 explains the detail of each circle and number of villages that comes under in each circle.

Table 4.1 Details of the circles of Dehon block

Name of the Circle	No. of the Villages
Siahar	13
Tibba	12
Dehlon	11
Ramgarh Sardaran	11
Malaudh	13
Gopalpur	10

4.3 BIOMASS POTENTIAL OF DEHLON BLOCK

Following steps are followed to calculate the biomass potential, so that power generated from biomass residue must fulfill the load demand of Dehlon Block.

4.3.1 INFORMATION OF AGRI-RESIDUE OF BLOCK DEHLON

The required data i.e. grain production per acre and residue to production ratio (R.P.R) of all the different crop residues was collected from block Agricultural Officer. Then from the above information total agri-residue per circle and total agri-residue of whole block is calculated.

Table 4.2 shows the different types of agri-residue crops, residue production ratio, crop yield/acre and agri residue production.

Table 4.2 Production and Categorization of main agri-residues

S.No	Agri-residue crop Types	Residue Production Ratio*	Crop Yield/Acre* (Quintal)	Agri-residue production (Quintal/acre)
1	Paddy Straw	1.9	31	58.9
2	Paddy Husk	0.2	40	8
3	Wheat Straw	1.16	24	27.84
4	Sugarcane (Tops and Leaves)	0.4	400	160
5	Maize (Stalk and Cobs)	2.6	33	85.8
6	Cotton (Stalks)	3.5	4	14
7	Mustard(Straw)	2.2	4.92	10.824

*Source: Dehlon Agricultural Officer

Tables 4.3-4.8 shows the total residue production by the crops in different circles of Dehlon Block

Table 4.3 Siahar Agri-residue Production

S.No	Agri-residue crop types	Crop Area (acres)	Per Acre Agri-residue production (Quintal)	Total Agri-residue (Quintal)
1	Paddy Straw	8610	47.8	411558
2	Paddy Husk	8710	8.1	70551
3	Wheat Straw	8750	25.6	224000*
4	Sugarcane (Tops and Leaves)	42	125	5250
5	Maize (Stalk and Cobs)	130	85	11050
6	Cotton (Stalks)	7.5	10.5	78.75
7	Mustard(Straw)	29.2	9.912	289.43
Total				722777

*Wheat straw (100%) is used as silage

Table 4.4 Tibba Agri-residue Production

S.No	Agri-residue crop types	Crop Area (acres)	Per Acre Agri-residue production (Quintal)	Total Agri-residue (Quintal)
1	Paddy Straw	10250	47.8	489950
2	Paddy Husk	10250	8.1	83025
3	Wheat Straw	10240	25.6	262144*
4	Sugarcane (Tops and Leaves)	50	125	6250

5	Maize (Stalk and Cobs)	151	85	12835
6	Cotton (Stalks)	10.1	10.5	106.05
7	Mustard(Straw)	34.1	9.912	337.99
Total				854648

*Wheat straw (100%) is used as silage

Table 4.5 Dehlon Agri-residue Production

S.No	Agri-residue crop types	Crop Area (acres)	Per Acre Agri-residue production (Quintal)	Total Agri-residue (Quintal)
1	Paddy Straw	7270	47.8	347506
2	Paddy Husk	7270	8.1	58887
3	Wheat Straw	7300	25.6	186880*
4	Sugarcane (Tops and Leaves)	35	125	4375
5	Maize (Stalk and Cobs)	105	85	8925
6	Cotton (Stalks)	9	10.5	94.5
7	Mustard(Straw)	25	9.912	2478
Total				6069155

*Wheat straw (100%) is used as silage

Table 4.6 Ramgarh Sardaran Agri-residue Production

S.No	Agri-residue crop types	Crop Area (acres)	Per Acre Agri-residue production (Quintal)	Total Agri-residue (Quintal)
1	Paddy Straw	8750	47.8	418250
2	Paddy Husk	8750	8.1	70875
3	Wheat Straw	8780	25.6	224768*
4	Sugarcane (Tops and Leaves)	44	125	5500
5	Maize (Stalk and Cobs)	125	85	10625
6	Cotton (Stalks)	8	10.5	84
7	Mustard(Straw)	25.8	9.912	255.73
Total				730358

*Wheat straw (100%) is used as silage

Table 4.7 Malaudh Agri-residue Production

S.No	Agri-residue crop types	Crop Area (acres)	Per Acre Agri-residue production (Quintal)	Total Agri-residue (Quintal)
1	Paddy Straw	10350	47.8	494730
2	Paddy Husk	10350	8.1	83835
3	Wheat Straw	10210	25.6	261376*
4	Sugarcane (Tops and Leaves)	50	125	6250

5	Maize (Stalk and Cobs)	155	85	13175
6	Cotton (Stalks)	11.5	10.5	120.75
7	Mustard(Straw)	30.2	9.912	299.34
Total				859786

*Wheat straw (100%) is used as silage

Table 4.8 Gopalpur Agri-residue Production

S.No	Agri-residue crop types	Crop Area (acres)	Per Acre Agri-residue production (Quintal)	Total Agri-residue (Quintal)
1	Paddy Straw	6990	47.8	334122
2	Paddy Husk	6990	8.1	56619
3	Wheat Straw	6845	25.6	175232*
4	Sugarcane (Tops and Leaves)	29	125	3625
5	Maize (Stalk and Cobs)	95	85	8075
6	Cotton (Stalks)	98	10.5	1029
7	Mustard(Straw)	17	9.912	168.5
Total				578871

*Wheat straw (100%) is used as silage

Table 4.9 shows the total agri-residue production of Dehlon block. Main agricultural residue contributor is paddy. Therefore, total agri-residue production was calculated to be 3018955 quintals apart from wheat because it is used as fodder.

Table 4.9 Block Dehlon Total agri-residue productions

S.No	Agri-residue crop types	Agri-residue Production (Circle Wise) (Quintal)						Total Agri-residue (Quintal)
		Siahar	Tibba	Dehlon	Ramgarh Sardaran	Malaud	Gopalur	
1	Paddy Straw	411558	489950	347506	418250	494730	334122	2496116
2	Paddy Husk	70551	83025	58887	70875	83835	56619	423792
3	Wheat Straw*	224000	262144	186880	224768	261376	175232	1334400
4	Sugarcane (Tops and Leaves)	5250	6250	4375	5500	6250	3625	31250
5	Maize (Stalk and Cobs)	11050	12835	8925	10625	13175	8075	64685
6	Cotton (Stalks)	78.75	106.05	94.5	84	120.75	1029	1513
7	Mustard(Straw)	289.43	337.99	247.8	255.73	299.34	168.5	1599
	Total	**722777**	**854648**	**606915**	**730358**	**859786**	**578871**	**4353355**

From above analysis, following observations are made –

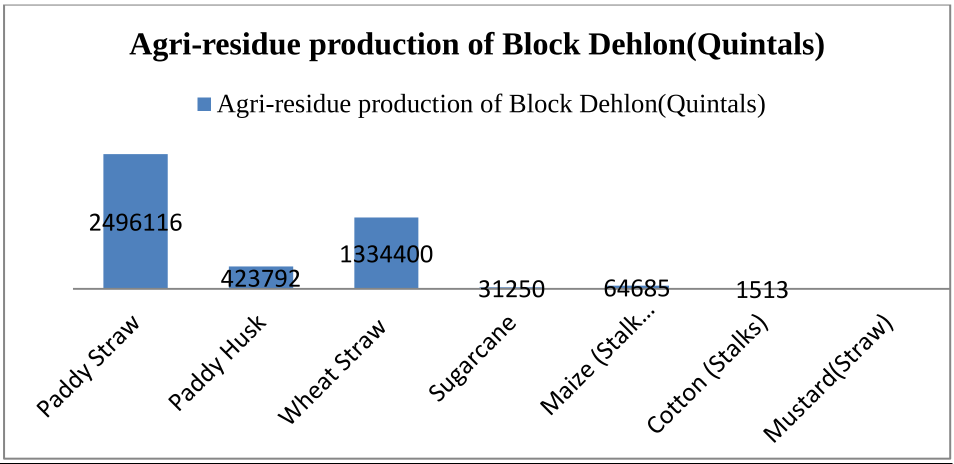
Total Agri-residue production = 4353355 Quintal

Since 100% wheat straw is used as silage

The available Total Agri-residue production=Total Agri-residue production- Total wheat straw

= 4353355 – 1334400 = 3018955 Quintals

Graph -4.1 shows the total agri residue production of different crops in Dehlon Block.



Graph 4.1- Total agri-residue production of different crops in Dehlon Block

4.3.2 CALORIFIC VALUES OF AGRI-RESIDUES

Bomb calorimeter is used to calculate the calorific value of different agri-residue crops. Different samples of crops are collected and then dried for at least a month for calculating their calorific value in bomb-calorimeter. Therefore amount of heat liberated from different agri residue crops can be calculated through their calorific value, further by which total energy value is determined.

4.3.2.1 BOMB CALORIMETER

It is constant volume type calorimeter which is used for measuring the heat of combustion of a particular sample. It is able to withstand large pressures because heavy reactions occur in this device. Therefore, it is basically the science of measuring quantities of heat, as distinct from “temperature’. The number of heat units liberated by a unit mass of a sample when burned with oxygen at constant volume is known as calorific value or heat of combustion. In order to continue the reactions the sample to be measured and the oxygen are initially kept at same temperature and the products of combustion are cooled. Difference is there in the initial and final temperatures of the bomb calorimeter i.e. temperature rise, which is so small that it can be neglected .Thus the term calorific value (or heat of combustion) denotes the heat liberated by the combustion of all carbon and hydrogen with oxygen to form carbon dioxide and water, including the heat liberated by the oxidation of other elements such as sulfur which may be present in the sample.

4.3.2.2 CALCULATION OF CALORIFIC VALUE

For calculating the calorific value, bomb calorimeter is used placed in the Non Conventional Energy Sources (NCES) Lab, of Electrical Department. For the same, briquetted sample of 1gram is taken in a nichrome crucible. To facilitate the ignition 15 cm long cotton is placed over the sample. Nichrome fuse wire is used to connect both the electrodes of bomb calorimeter. Oxygen is filled in the calorimeter at a pressure of around 25 to 30 atm. The distilled water (2 Liter) is stirred continuously until homogenous mixture is obtained in the bucket by passing current through the fuse wire, there is rise in temperature of water and this is recorded automatically.

Gross Calorific Value (G.C.V.) = $\frac{(\text{Water equivalent}\times \Delta\text{T}-27.1-4)}{\text{Weight of the sample}}$

Where ΔT is the maximum rising temperature

Water equivalent = $\frac{6318(\text{wt of sample}) + \text{CV of nicrome wire} + \text{CV of cotton wire}}{\Delta T}$

1. GCV of wheat is:-

Wt of sample = 0.815 gm

Initial temperature = t_1=1.16^{0}C

Final temperature = t_2 = 2.28^{0}C

Rise in temperature = 1.12^{0}C

Water equivalent= $\frac{6318(0.612) +27.1+4}{1.35}$

=2887.197

GCV of wheat straw = $\frac{[2887.197*1.12]-27.1-4}{0.815}$

= 3929.5222 Kcal/kg

= 393000 kcal/ Qt

2. GCV of rice:-

Wt of sample = 0.847 gm

Initial temperature = 1.18^{0}C

Final temperature = 2.18^{0}C

Change in temperature = 1.00^{0}C

GCV of rice straw = $\frac{[2887.197*1]-27.1-4}{0.847}$

= 3372.0153 kcal/ kg

= 337200 kcal/ Qt

Similarly for all the other samples:-

Sugarcane = 407800 kcal/ Qt

Paddy husk = 395300 kcal/ Qt

Maize straw = 403000 kcal/ Qt

Cotton stalk = 429200 kcal/Qt

Mustard stalk = 415500 kcal/Qt

Table 4.10 shows the total energy liberated from agricultural residues.

Table 4.10 Total energy content from available agri residue

S.No	Agri-residue crop types	GCV (kcal/ Qt)	Agri-residue available (Quintal)	Energy Value (kcal)
1	Paddy Straw	337200	2496116	8.4×10^{11}
2	Paddy Husk	395300	423792	1.6×10^{11}
3	Sugarcane(Tops and leaves)	407800	31250	12743750000
4	Maize Stalk	403000	64685	$.26\times10^{11}$

5	Cotton Stalk	429200	1513	649379600
6	Mustard Straw	415500	1599	664384500

Total energy value = 1040057514100 kcal`

Overall efficiency of plant is 22%

Energy value of total utilizable biomass obtained at 22% thermal efficiency

= 22% of 1040057514100

= 228812653102 kcal.

Now 1 kcal= .001163 kWh

So Energy value (kWh) = 266109115.557 kWh.

For 8760 hours of operation,

Potential of biomass power in block Dehlon = 30377.75 kW

= 30.38 MW .... (1)

4.3 LOAD DEMAND OF BLOCK DEHLON

The loads are divided into three categories:-

1. Residential load
2. Agricultural load
3. Commercial load

In order to fulfill the power demands of Dehlon Block the potential of the plant is required to be matching the load demand. The data of connected load of is provided by PSPCL. Tables from 4.11 to 4.16 show the load calculations of different circles.

Table 4.11 Siahar Load calculations

S.No	Load Type	Consumer Number	Load(kW)
1	Commercial	300	550
2	Residential	4532	6580

3	Agricultural	1630	9850
Total Load			16980

Source- PSPCL

Table 4.12 Tibba Load calculations

S.No	Load Type	Consumer Number	Load(kW)
1	Commercial	310	560
2	Residential	5200	7581.68
3	Agricultural	1860	11122
Total Load			19264

Source- PSPCL

Table 4.13 Dehlon Load calculations

S.No	Load Type	Consumer Number	Load(kW)
1	Commercial	230	425
2	Residential	3712	5565
3	Agricultural	1344	7920
Total Load			13910

Source-

PSPCL

Table 4.14 Ramgarh Sardaran Load calculations

S.No	Load Type	Consumer Number	Load(kW)
1	Commercial	270	480
2	Residential	4270	6310
3	Agricultural	1598	9535
Total Load			16325

Source- PSPCL

Table 4.15 Malaudh Load calculations

S.No	Load Type	Consumer Number	Load(kW)
1	Commercial	320	580
2	Residential	5082	7520
3	Agricultural	1820	11100
Total Load			19200

Source- PSPCL

Table 4.16 Gopalpur Load calculations

S.No	Load Type	Consumer Number	Load(kW)
1	Commercial	220	390
2	Residential	3350	5020
3	Agricultural	1200	7200
Total Load			12610

Source- PSPCL

Table 4.17 shows the total load of Dehlon Block

Table 4.17 Block Dehlon Load calculations

S.No	Load Type	Consumer Number	Load(kw)
1	Commercial	1650	2985
2	Residential	26146	38577
3	Agricultural	9452	56727
Total Load			98289kw

Total electrical load of the Block Dehlon = 98289 kW

= 98.2 MW .... (2)

4.4 COGENERATION PLANT INSTEAD OF STANDALONE BIOMASS PLANT

Considering equations (1) & (2), it is concluded that the load demand is 98.2 MW while the potential of standalone biomass plant is 30.38 MW. Consequently, the biomass plant alone is not able to fulfill the load demands and hence auxiliary power generation is required to meet the demands of the people. As a result, biomass cogeneration plant is proposed by using MHD generator and thermo electric generator to meet the required demands.

The feasibility and the specifications of the biomass cogeneration plant are selected so as to match the capacity of all units in cogeneration plant. Refer to figure 1.16 which shows that the flue gases which are released from the boiler are fed to MHD generator where the MHD performs its functioning. As the biomass is used as fuel and when it is burned it gets decomposes and releases many gases. The products after combustion are H_2O, nitrogen combines with oxygen and forms $NO_{X,}$ and carbon also gets attached with oxygen to form CO, C or $CO_{2.}$ Along with these gases also contains 0.3% of nitrogen, 0.1% of sulphur which can combine with oxygen during burning and can form SO_2, chlorine with little amounts of Calcium, Potassium, phosphorous etc. These flue gases are then passed to MHD generator along with the seeding material. Firstly it is required to calculate the amount of flue gases and its heat flow which can result in optimum running of the plant.

4.4.1 MATCHING THE CAPACITY OF BIOMASS PLANT WITH MHD GENERATOR

Nomenclature

V_{GOD} = Flue gas volume (m^3/kg)

ɤc = carbon content of fuel (by mass in kg)

$ɤ_H$ = hydrogen content of fuel (by mass in kg)

$ɤ_N$ = nitrogen content of fuel (by mass in kg)

γ_S = sulphur content of fuel (by mass in kg)

γ_{water} = water content of fuel (by mass in kg)

$H_{N(d)}$ = net calorific value (MJ/kg)

S = fuel factor

V_{GOD} = flue gas flow rate

The formulas used here are:-

Heat released = fuel factor x net calorific values

Dry flue gas flow rate = heat release x fuel factor

Given fuel factor for solid = 0.256 (dry form)

= 0.359 (as received contains moisture)

Calculation of flue gas flow rate

V_{GOD}= 8.8930γ_C + 20.9724γ_H +3.3190γ_S – 2.6424γ_O +0.7997γ_N in m^3/kg …………… (3)

The above equation is valid for calculating the flue gas flow rate of solid form in as received i.e. containing moisture in it.

V_{GOD} = -0.06018(1-γ_{ASH} -γ_{H20}) +0.25437(H_N +2.4425 γ_{H20}) …………… (4)

For calculating the dry gases the moisture content is neglected and moreover the moisture content is also very low so it is possible. The resulting equation 4 can be written as:-

V_{GOD} = -0.06018 + 0.25437 $H_{N(D)}$

Where $H_{N(D)}$ =28.33 (standard)

Putting the below values in equation (4):-

γ_C = 0.718	γ_S = 0.010
γ_H = 0.045	γ_{WATER} = 0.130
γ_N = 0.015	γ_0 = 0.082

V_{GOD} = 7.16 m^3/kg (dry form)

S= V_{GOD}/$H_{N(D)}$

= 7.16/28.33 = 0.2526 m^3/MJ

Putting the values in equation (3):-

V_{GOD} = 6.23 m^3/kg (moisture form)

S = V_{GOD}/H_N

= 6.23/24.33

= 0.2559 m^3/MJ

Therefore, flue gas flow rate = 0.2559 m^3/MJ

Now heat released = $\frac{\text{flue gas flow rate}}{\text{fuel factor}}$

= 7.16/0.2559

= 27.96875 MJ/kg

Since 1MJ =238.845 kcal

Therefore heat released = 6680 kcal/kg (approx.)

Amount of heat released = 668000 kcal/Qt

Flue gas flow rate = 0.2559 m^3/MJ

Mass flow rate of flue gases = 955 kg/s

Now, it is clear that when biomass is used as raw material and its combustion processes will lead to formation of flue gases and the heat released is also sufficient to cause the flow in MHD generator as the mass flow rate of the flue gases is 955 kg/s and for the working of MHD generator the required mass flow rate is 952 kg/s.

4.5 BIOMASS POWER PLANT MODEL

All the essential points are focused to propose the biomass power plant model and are as under-

4.5.1 EXPECTED LOCATION DETAILS OF THE PLANT

Village – Malaudh

Address of Block – Dehlon

District – Ludhiana

State – Punjab

Longitude – $76^0$54 E

Latitude – $30^0$55 N

4.5.2 TECHNICAL DETAILS OF THE PLANT

The specifications of the major equipments used in standalone biomass plant are as follows-

4.5.2.1 TECHNICAL DATA OF EQUIPMENTS IN STANDALONE BIOMASS PLANT

Boiler data (hot water boiler / steam boiler)

a.	Number of boilers	:	One (hot water boiler/ steam boiler)
b.	Boiler efficiency %	:	70%
c.	Steam pressure at SH outlet	:	44 atm
d.	Feed water inlet temperature	:	105 Deg C
e.	Steam temp. at SH outlet	:	450 Deg C
f.	MCR capacity	:	12.50 tph

Steam turbine (Siemens Pelton steam turbine)

a.	Power rated	:	1000 kW
b.	Inlet steam temperature	:	445 Deg C
c.	Inlet steam temperature	:	445 atm

Steam flow

a.	Flow	:	1.04 tph
b.	Pressure	:	3.50 atm
c.	Temperature	:	191 Deg. C

Condenser (Air Cooled flue gas condenser)

a.	Steam flow	:	10.16 t/hr
b.	Number of Modules	:	Two

c.	Wind Wall	:	Provided
d.	Number on Streams	:	One

Condensate Extraction Pump & Steam Ejectors

a.	Type	:	Centrifugal
b.	Suction pressure	:	0.13 atm
c.	Capacity	:	10 m^3/hr
d.	Number of pumps	:	2 (2 x 100%)
e.	Discharge pressure	:	5.0 Kg/sq.cm g
f.	Steam Ejectors	:	2 (2 X 100%)
g.	Starting Ejector	:	1
h.	Hot Well Pumps	:	2X100%
i.	Hot well Tank	:	1X 100%
j.	Condensate Tank	:	1 No

Aux Cooling water system

a.	Type of cooling tower	:	Induced draft
b.	Capacity	:	150 m^3/hr
c.	Number of cooling towers	:	One (1)
d.	Cooling water return temperature	:	41 Deg. C
e.	Cooling water supply temperature	:	32 Deg. C
f.	No. of cells	:	Two
g.	Cooling water return pressure	:	0.5 Kg/sq.cm
h.	Evaporation loss and blow down %	:	2.0

Boiler Feed Pumps

a.	Number of pumps	:	Two (2 x 100%)
b.	Type	:	Multistage
c.	Drive	:	Electric motor with soft starter

d.	Capacity m³/hr.	:	13
e.	Head MLC	:	570

Water

a.	Water requirement	:	6.74 m³/hr
b.	Water sources	:	Ground water

Generator Parameters

a.	Rating	:	1000 KW
b.	Applicable Standard	:	IEC-34
c.	Rated speed (rpm)	:	1500
d.	Rated power factor	:	0.8
e.	Rated frequency (Hz)	:	50
f.	Excitation system	:	Brushless
g.	Voltage	:	415 V
h.	Enclosure	:	IP-55
i.	Cooling	:	Air cooled
j.	Insulation class	:	F
k.	Efficiency @ rated output,	:	70%
l.	Power Factor	:	0.8

4.5.2.2 CONTROL & PROTECTION SYSTEM

The following protections are proposed to be provided for the generators:

1. Differential protection - Differential protection is the main protection provided in the stator winding to provide protection against phase to phase or phase to earth fault.

2. Stator earth fault protection – When the stator neutral is earthed through resistor and current transformer is mounted in neutral to earth; that protection is called stator earth fault protection. It is done to provide protection against high voltage at the stator winding.

3. Reverse power relay protection - Power relay is used to provide protection against the reverse power which arises due to accumulation of negative charges at the output side of the generator.

4. Over voltage protection – The protective relays used to prevent the damages caused due to high voltages or the voltage exceeding the limited value is called as over voltage protection.

5. Under voltage protection – The protective relays used to prevent damages caused due to low voltages or the voltage below the value required to start the generator is called as under voltage protection.

6. Instantaneous over current earth fault protection – This type of protection is used to detect the faults occurring inside and outside the generator and thus prevents the generator from getting damaged.

4.6 HYBRID MODEL

The hybrid model is made with the help of MHD and thermoelectric generator so as to fulfill the load demands of Dehlon Block.

4.6.1 MHD GENERATOR MODEL

The MHD generator calculations and specifications are discussed below:-

4.6.1.1 MHD GENERATOR CALCULATION CONDITIONS

As MHD (magneto hydro dynamic) is simply the study of plasmas at high temperatures exposing to the strong electromagnetic fields so as to get the electrical power generation. It specially deals with the flow of combustion plasmas in presence of magnetic fields. The combustion plasmas are a kind of fuels generated by burning of fuel in high pressure and high temperature in addition with any ionizable substance. Along with this a seeding material is also added so as to increase the electrical conductivity of gas resulting in high output from generator. In this combustion type pulsed generator is used which is fired by an independent high pressure, high temperature combustor to produce high velocity plasma. The flue gases along with ionizable material aluminum oxide is used as combustor and to increase its pressure the entrance channel is kept small in diameter as compared to the outlet channel and thus resulting in the increase in pressure which further helps in increasing the velocity of plasma which is the main requirement for working of the MHD generator. While plasma is passing through the channel; seeding material which can be potassium or cesium (easily gets ionized at low temperatures also) is added so as to increase the electrical conductivity of gas resulting in the output from the generator. The output of this generator varies from 100 to 510 MW. The view of MHD generator showing its specifications is drawn under:-

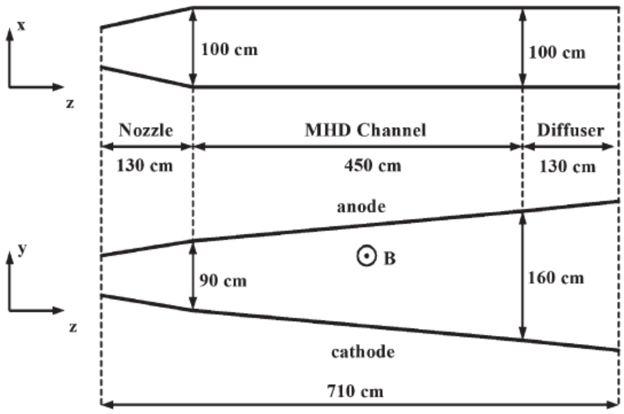


Fig 4.1 Channel shape and coordinate system of MHD generator

4.6.1.2 OPERATING CONDITIONS

A. MHD Channel type

A typical representation of MHD generator is shown in figure 4.2 in which the channel inlet nozzle is of 1.3m, MHD channel of 4.5m, and diffuser of 1.3m. The fluid or plasma enters the inlet channel to the channel exit. The channel inlet and exit are 0.9 x 1.0m and 1.6 x 1.0m and the entrance of the plasma occurs at the uniform rate at pressure of 3.5×10^5 Pa.

B. Working Gas

For the functioning of MHD generator the working plasma is required. It contains about 40% of liquid particles of Al_2O_3 in weight and seeding material is also added (potassium or cesium) so as to increase the electrical conductivity of gas.

This gas is then passed through the channel in the existing magnetic field where the current is produced through the Faraday's law which states that the electric field is generated when a conductor or hot plasma passes through the magnetic field.

The generated electric field or output generated is directly proportional to the speed and intensity of magnetic field. Thus high electrical conductivity, speed of conducting medium as well as strong magnetic field is vital features to generate high electrical power. Therefore it is an easy way to convert heat energy directly into electrical energy without any intermediate mechanical energy conversion and is used prominently.

Output

It is calculated that the plasma enters the channel at static pressure of $3.5x10^5$ Pa, which falls along the channel to $2.8*10^5$ Pa after travelling through the axial distance of 2.8m and thereafter the pressure again increases to about $3.07*10^5$ at the channel exit. It is also concluded that the high temperature and high intensity of magnetic field results in high value of electric current. Therefore the temperature of the channel is kept very high to get the high output. The temperature is kept at 2739K at the inlet channel and increases to 2849K at the exit channel; on the other hand the velocity of the plasma is decreased by 27% during its flow. The temperature is required to be high so as to increase the electrical conductivity by 68% with respect to input and consequently the output is very high as required. Since for the calculations, the load factor is assumed to 0.7 which results in the output voltage to 2704V and the total power output of this is 505.5 MW which is very high and can be fulfilled.

4.6.1.3 TECHNICAL DETAILS OF MHD GENERATOR

The technical details of the MHD generator are explained below-

a. Mass flow rate (kg/s) : 952.0

b. Length of channel (m) : 4.5

c. Inlet height & width of channel (m) : 0.9 & 1.0

d. Exit height & width of channel (m) : 1.6 & 1.0

e. Magnetic field strength (T) : 2.09

f. Wall static temperature (K) : 2300

g. Inlet static temperature (K) : 2750

h. Inlet static pressure (Pa) : 3.5×10^5

i. Loading factor : 0.70

j. Working fluid : aluminum oxide

4.7 SIMULINK MODELS

The designing of both the power plants is compiled by using MATLAB-simulink and discuused in detail further.

4.7.1 BIOMASS STANDALONE PLANT

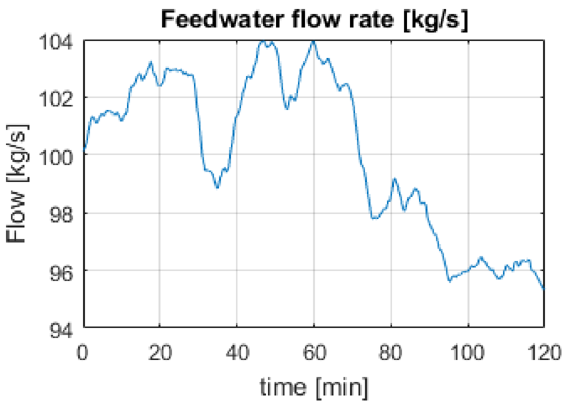
For the working of the simulink model the first step is to calculate the transfer functions and the boiler efficiency to get the required output. The steps followed are-

Step 1:- Boiler Coding

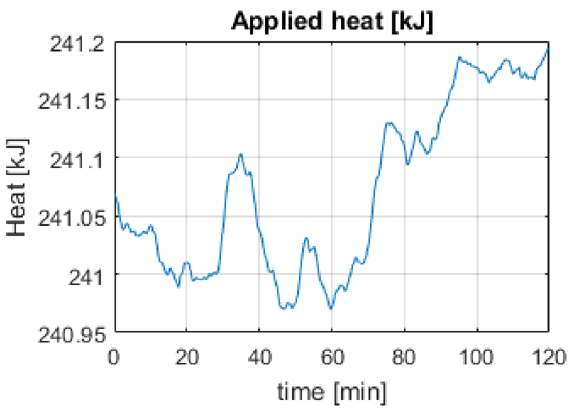
Source Code for Boiler

```
opspec = operspec('Boiler');

opspec.States(1).Known = 1;

opspec.States(2).Known = 1;

opspec.States(3).Known = [1;1];

opspec.Inputs(1).Known = [0;0];

opspec.Inputs(1).Min = [0;0];

Boiler_io(1) = linio('Boiler /Sum',1,'input');

Boiler_io(2) = linio('Boiler /Demux',2,'input');

Boiler_io(3) = linio('Boiler /Boiler',1,'openoutput');
```

```
setlinio('Boiler’,Boiler_io);

u0 = opReport.Inputs.u;

y0 = opReport.Outputs.y;

Q = diag(1e8);

R = diag([1e2,1e6]);

[K,S,E] = lqry(Lin_Boiler,Q,R);

[A,B,C,D] = ssdata(Lin_Boiler);

G = [B(:,1)];

H = [0];

QN = 1e4;

RN = 1e-1;

NN = 0;

[Kobsv,L,P] = kalman(ss(A,[B G],C,[D H]),QN,RN);

figSize = [0 0 360 240];

h = figure(1); plot(FeedWater.time/60,FeedWater.signals.values)

h.Color = [1 1 1];

h.Position = figSize;

title('Feedwater flow rate [kg/s]');

ylabel('Flow [kg/s]')

xlabel('time [min]')

grid on
```




```
h = figure(2); plot(Heat.time/60,Heat.signals.values/1000)

h.Color = [1 1 1];

h.Position = figSize;

title('Applied heat [kJ]');

ylabel('Heat [kJ]')

xlabel('time [min]')

grid on
```



STEP 2:- Generate the Transfer Function of Turbine

In the previous case, it was estimated that the efficiency of the biomass plant is 22% thus it can be written as 0.2 and also the standard form of transfer function is-

$$= \frac{K(z+a)(z+b)\ldots\ldots}{(p+x)(p+y)\ldots\ldots..}$$

Where K = gain stability constant

z= zeroes and p= poles

1. Taking 0.2, 1-0.2= 0.8 which is the stability point of the zeros lying in jω axis, indicating the functioning of the turbine. Then converting it into s domain, the numerator comes out to be:-

= K(s+0.8)

2. For the gain stability factor, the term taken must be constant i.e. convergent efficiency of turbine which carried the process of converting the steam into electricity and that maximum efficiency is 40% neglecting the losses.

Therefore K = 0.04

Numerator= 0.04(s+0.8)

3. The poles in the denominator are considered as the range of the turbine up to which it can extend and for that case the values are taken from 0 to 1such that the range will cover the minimum and maximum efficiency at the output side without considering any losses or neglecting the transients.

Denominator = s(s+1)

4. The resulting transfer function is

$$= \frac{0.04(s+0.8)}{s(s+1)}$$

The simulink model of the biomass plant is shown in figure 4.2(a)

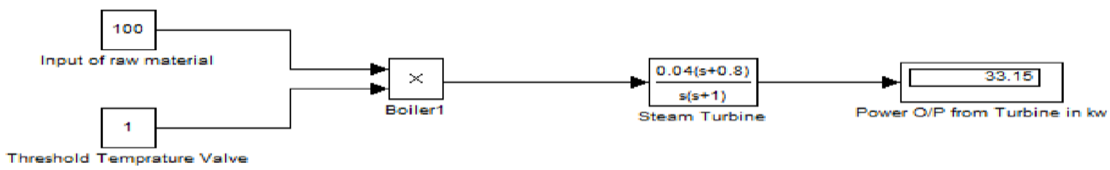


Fig 4.2 (a) Simulink model of standalone biomass plant

The next step is by changing the values at the input side or changing the raw material and the efficiencies are recorded. Figure 4.2 (b) shows simulink model of standalone plant by changing the input value.

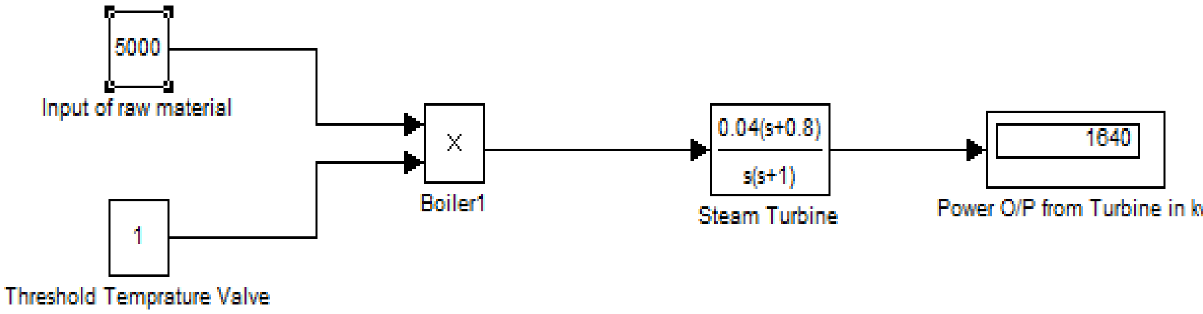


Fig 4.2 (b) Changed simulink model of standalone biomass plant

Consequently, the efficiency of both the above models recorded -

From figure 4.3 (a):- 33.15%

From figure 4.3 (b):- 1640/5000 = 0.328

= 32.80%

Subsequently, the efficiency of the normal biomass plant remains almost 33%. By changing the input raw material, it is accomplished that the efficiency will remain constant i.e. near to 32 to 33%.

4.7.2 SIMULINK MODEL OF HYBRID PLANT

For the working of simulink model of hybrid plant, the first step is to determine the transfer function of the model and then the efficiency of hybrid plant is calculated.

STEP 1: Generating the Transfer Function of TEG and MHD generator

1. For MHD power generation also the basic concept is same that is the heat energy is converted into electrical energy.

Therefore K will remain 0.04 and the standard form of transfer function is-

$$= \frac{K(z+a)(z+b)\ldots\ldots}{(p+x)(p+y)\ldots\ldots..}$$

Where K = gain stability constant

z= zeroes and p= poles

2. Taking 0.2, 1-0.2= 0.8 which is the stability point of the zeros lying in jω axis, indicating the functioning of the turbine. Then converting it into s domain, the numerator comes out to be:-

= K(s+0.8)

3. Numerator= 0.04(s+0.8) (for both TEG &MHD)

4. The poles of the denominator are so selected to consider the efficiency range (0-1) of the MHD &TEG. Value of 1gets divided into 0.5 as it is fed to MHD &TEG generator. Resulting transfer function of MHD neglecting the losses comes out to be:-

$$\frac{0.04(s+0.8)}{(s+0.5)(+0.25)}$$

0.25 is the efficiency of the working of the MHD itself.

5. The transfer function for the hybrid simulink model is:-

$$\frac{0.04(s+0.8)}{(s+0.5)(s+0.25)}$$

The simulink model is completed using MATLAB. Figure 4.3 (a) shows the simulink model of hybrid plant.

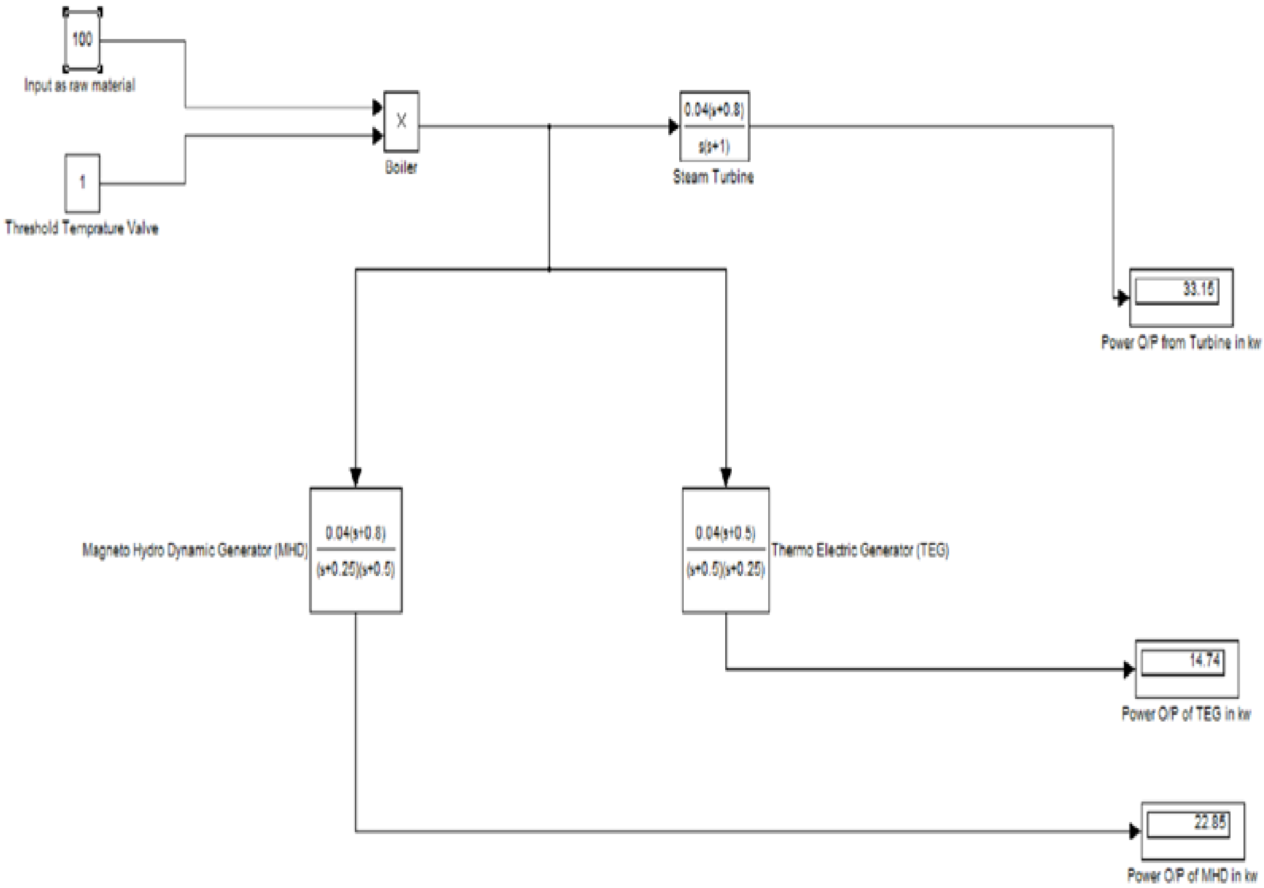


Fig 4.3(a) Simulink model of hybrid plant

Calculation of efficiency of the hybrid plant -

= Turbine + MHD + TEG

= 33.15% + 14.74% + 22.85%

= 70.74%

By changing the amount of raw material fed to the boiler or by changing the values at the input side, the efficiency is calculated. Figure 4.3 (b) shows the simulink model of hybrid plant with changed value.

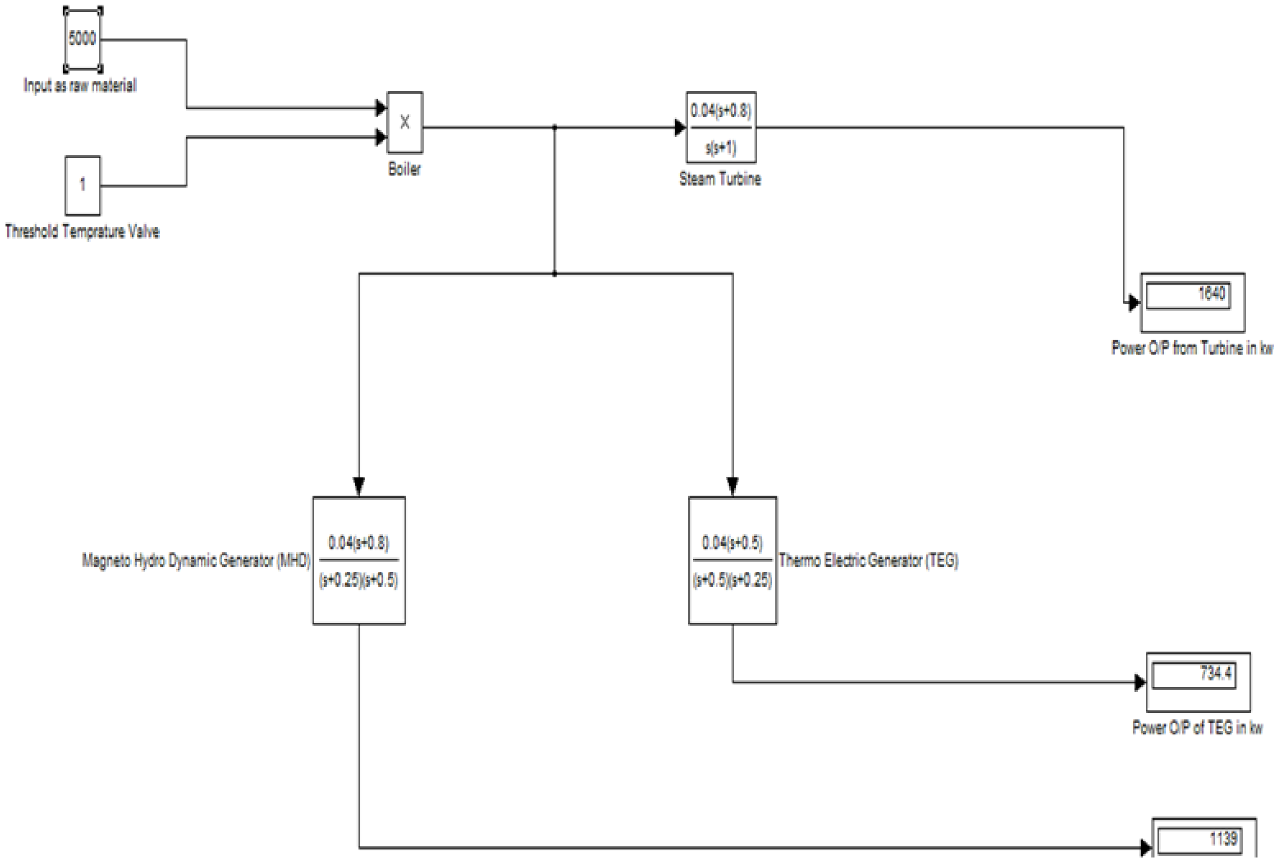


Fig 4.3 (b) Changed simulink model of hybrid plant

By taking 5000 as input (raw material), output is -

=1640 + 734.4 + 1139

=3513.5

Efficiency = output/ input

= 3513.5/5000

= 0.702

= 70.2%

From the above observations, it is concluded that the efficiency of the hybrid plant will remain 70% to 71% even by changing the amount of raw material.

Table 4.18 shows the comparison table of both plants by putting different values and their outputs.

Table 4.18 Comparison table standalone and hybrid plant

S.No.	Input raw material (kg)	Output of Turbine (kW)	%age power generated	Hybrid output (kW)	%age power generated
1.	20000	6560	32.80%	14052	70.26%
2.	10000	3281	32.81%	7028	70.28%
3.	5000	1640	32.80%	3513.4	70.27%

Consequently, the efficiency of normal biomass plant is 33% approximately and that of hybrid plant is 70% which is almost double and thus it is estimated that hybrid plant is far better for installing instead of standalone biomass plant and reducing the cost per unit of the plant also.

4.8 ESTIMATING THE COST OF BOTH THE PLANTS

1. Installed capacity(kW) = 1000
2. Cost of the plant (Rs.) = Rs. 50000000
3. Cost/ kW = Rs. 50000
4. Interest on capital during construction @15% on (2) = Rs. 7500000
5. Total (2)+(4) = Rs. 57500000
6. Cost/kWh including interest = Rs. 57500
7. Annual generation in kWh = 1000×0.7× 365×24 = 6132000 kWh
8. Auxiliary consumption @7% on (7) = 429240kwh
9. Units sent out (7) - (8) = 5702760 kWh
10. Fuel consumption= kg/kWh = 1.15
11. Fuel Consumption/year (10)×(7)= kg= 7051800
12. Annual cost at Rs.1200/tone (FY 2013-14) :(1200/1000)×(11)= Rs. 8462160

13. Fixed Charges

(a) Interest charge @15% on (5) = Rs. 14375000

(b) Operation and Management charges = Rs. 2500000

(c) Depreciation charges = Rs. 2000000

14. Total Fixed and running charges per year (12)+ (13) = Rs. 40942160

15. Cost/kWh generated (14)/(7) = Rs. 6.68

16. Total requirement of fuel/year (11)×.001 = 7051.8 tones

17. Requirement of fuel/day = 19.31 tones

18. Requirement of fuel/day = .80 tones

19. Working hours per day : 24

20. Plant useful life : 20 years

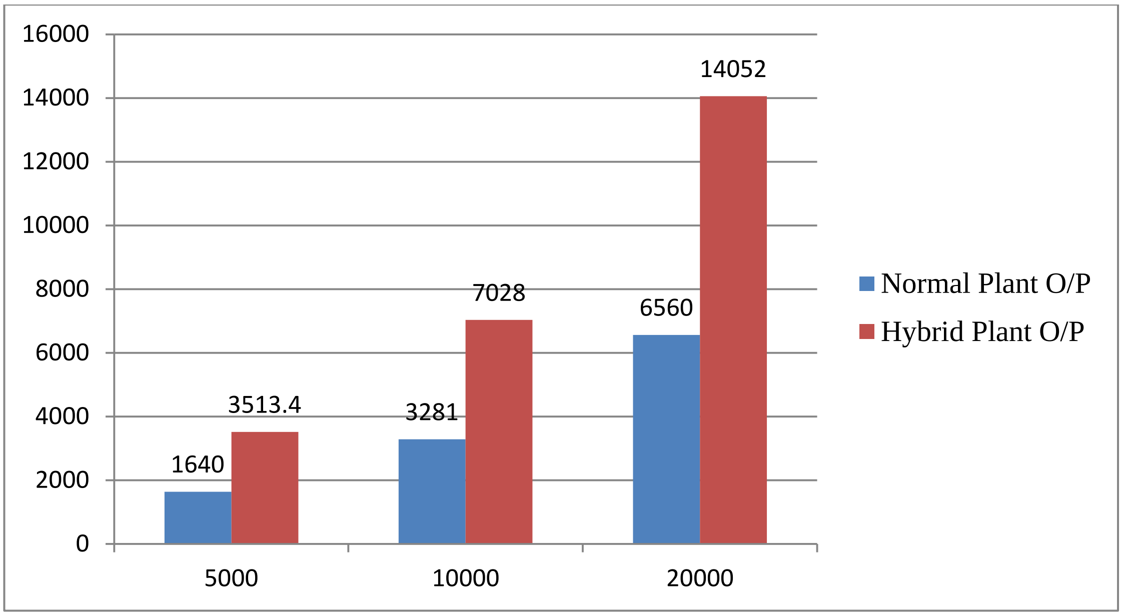
21. Biomass stock needed : 4 Months

The cost per unit of the expected biomass plant is Rs.6.68 and it is proved from the above that if the efficiency of the hybrid is double from the normal biomass plant, then cost will also reduced to half. Hence the cost per unit of the hybrid plant will become Rs.3.34 i.e. in the range of Rs. 3-4.

4.9 COMPARISON OF BIOMASS AND HYBRID PLANT

Both the standalone and hybrid plant are compared on the basis of input, output, efficiency and cost per unit.

A) In Terms Of input & output - Graph 4.2 shows the comparison between the input in the form of raw material in kg and the power output in kW of both the standalone biomass plant and the hybrid plant.



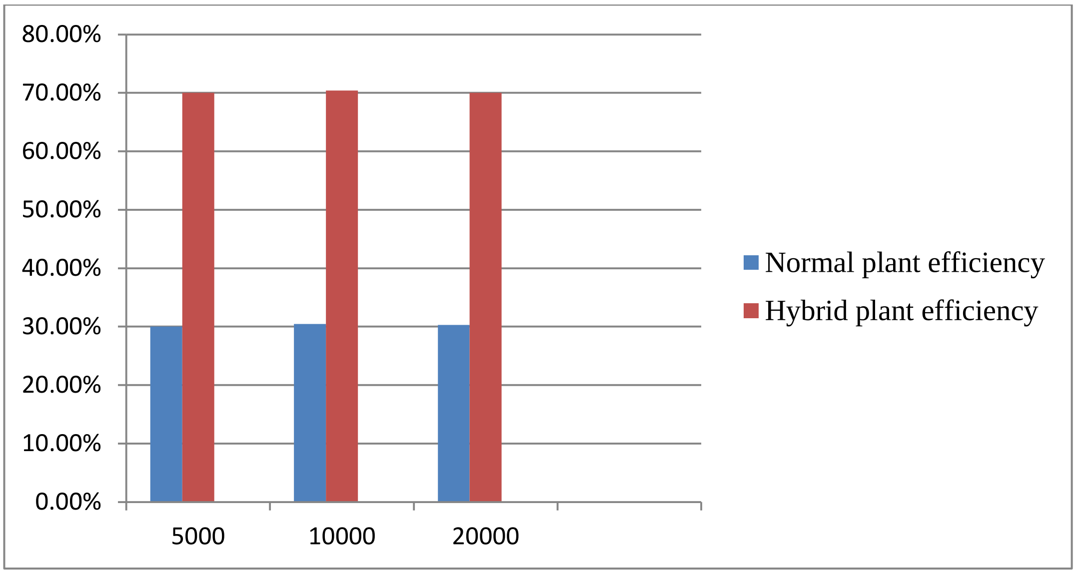
X-axis shows the input of raw material in kg

Y-axis shows the output in kW

Graph 4.2- Comparing the output of hybrid and standalone plant

It is seen that when the input is same for the normal and hybrid biomass plant, the output of hybrid plant is almost the double from the normal plant, thus making it more efficient.

B) In Terms of Efficiency: - Graph 3 shows comparison on the basis of efficiency of both normal and hybrid plant.



X-axis shows the input of raw material in kg

Y-axis shows the efficiency in percentage

Graph 4.3- Comparing the efficiency of hybrid and standalone biomass plant

It is observed that efficiency of the hybrid plant is double from the standalone plant, reducing the cost per unit of the hybrid plant also.

4.10 ADVANTAGES OF HYBRID PLANT

Advantages of the hybrid system are -

1. EFFICIENCY

In normal working biomass plant the efficiency of the plant is about 20-35% (source-world biomass energy resource center) but in hybrid efficiency is up to 60-75%. Since there are three outputs i.e. MHD, biomass and TEG. Output from thermoelectric generator is utilized by the plant itself for its own functioning like in cooling systems, power requirement etc. The conversion efficiency of MHD system is around 50% higher from normal generators plants and even more efficiencies are expected in future i.e. 60-65%. If by chance one output is hindered due to any problem then power generation is continued with the help of backup system; resulting in increasing the reliability of plant.

2. ENVIRONMENT FRIENDLY

Biomass is a very important energy source for generation due to its properties like renewable, widely available and carbon neutral. Therefore plants using biomass are being promoted day by day for generation of power. In biomass plants the left out materials of field processes are utilized in a better way and helps in clearing out the wastes and promoting a clean environment. Therefore, cogeneration systems are environment friendly as they helps in clearing and utilizing the wastes in a better way.

3. CONTINUES POWER SUPPLY

The biomass plants give us the power from raw material and if in case one system is out of order, then power supply is given continued from another part, resulting in continues power supply. Moreover the villages have lots of waste material present and hence it can be recommended in every village and by this waste material can also be eliminated.

4. MULTI OUTPUT SYSTEM

Cogeneration system is a multi output system which fulfills the load demands and the available extra energy can also be sold to power grid resulting in profit.

5. SMALL IN SIZE

As compared to other cogeneration systems the size of this plant is small in MHD generator and TEG there are no moving parts. The working of the plant is quite simple. Smaller the size of the plant, more it is easy to handle the whole system.

6. POWER AT AFFORDABLE RATES

As the efficiency of hybrid plant is double from the normal working plant; therefore the cost will also be reduced providing power at affordable rates.

As a result, it is better to use a hybrid plant than to use the standalone biomass plant.

CHAPTER-5

RESULTS AND DISCUSSION

The results of both the standalone and hybrid biomass plant are as under:-

1. Total biomass production of the block Dehlon is **3018955 quintals** and potential from this available biomass comes out to be **30.38 MW.**

2. Total connected load of the block Dehlon, Punjab is **98.2 MW** which includes 2985 kW commercial load, 38577 kW residential loads and 56727 kW agricultural load.

3. Remaining load demand is fulfilled by the hybrid plant with the help of MHD generator and thermoelectric generator and the potential of the hybrid plant is **100 MW** approx.

4. Efficiency of the biomass plant comes out to be **32.80%** while that of hybrid plant is **70.28%.**

5. Cost per unit of the biomass plant is **Rs.6.68/kWh** and on the other hand, the cost per unit of the hybrid plant is **Rs.3.34/kWh.**

6. It is concluded that using a hybrid plant of biomass with the help of MHD generator and thermoelectric generator is far better than standalone biomass plant.

7. Comparison of both the plants is shown in the graphs:-

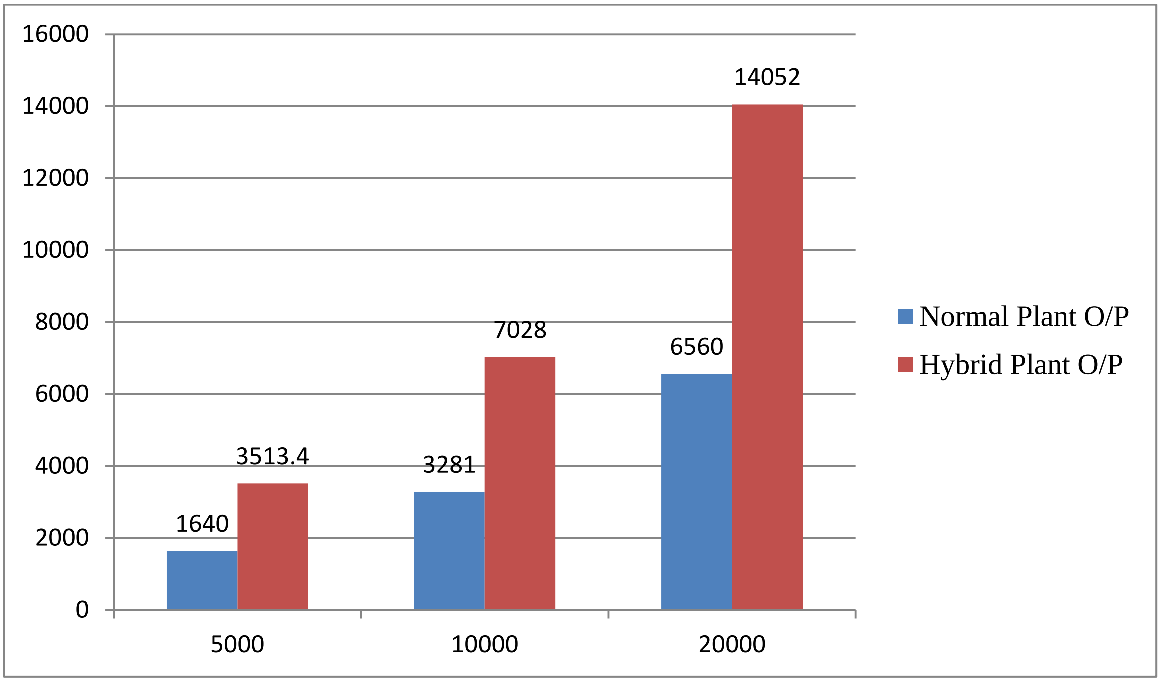
a) In terms of input & output:-

The graph is made by taking the inputs and outputs of both the plants by which it is concluded that output from the hybrid plant is almost double the normal biomass plant, thus double output is received from the hybrid plant with the same input to both plants.

b) In terms of efficiency:-

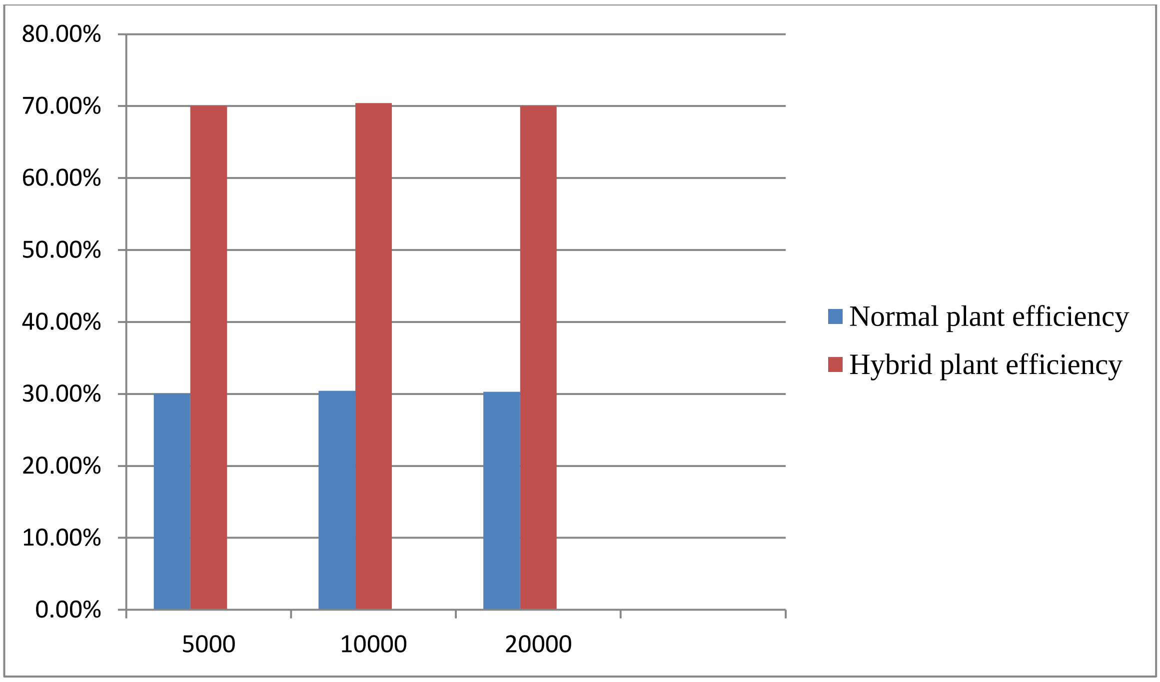
The graph is made by the efficiencies received from both the plants and is observed that efficiency of the hybrid plant is also almost double from the standalone plant, thus reducing the cost per unit of the hybrid plant also.

a) In terms of input/ output-



X- axis shows the input of raw material in kg & Y-axis shows the output in kW

b) In terms of efficiency-



X-axis represents the input of raw material in kg &Y-axis represents the efficiency

CHAPTER- 6

CONCLUSION AND FUTURE SCOPE

This study provides a new approach or new idea for using the renewable technologies to meet the rising power demands and to conserve other sources of energy. Consequently, biomass cogeneration is done with MHD generator and thermoelectric generator for the power generation in India. By using all the feasibility conditions the plant can be set up in all the villages due to the availability of raw material. Through this, plants of high capacity can be made which can fulfill the demands. In the thesis, the capacity of the biomass plant is 30MW and the capacity of hybrid plant is 100 MW (or above) and power demand of the block is about 92 MW. The cost per unit of power generation is Rs.3-4/ kWh. The biomass is utilized as fuel which is able to run the plant and the flue gases which arise from the boiler are fed to MHD along with insulating and seeding material. The efficiency of the hybrid plant is high i.e. 72 % due to which availability of power is at affordable rates and in excess amount.

It is concluded that not only the efficiency and reliability of the plant is increased, but the cost per unit is also decreased which adds to the feature for the designing of the plant. Moreover, the biggest advantage is that using the renewable sources of energy for power generation helps in the conservation of sources of energy. The benefits of the hybrid plant are briefly explained in points:-

1. It reduces pollution.
2. Biomass which is used as raw material is a renewable source of energy.
3. Efficiency is increased up to 40%.
4. Cost per unit of the plant is also very less.
5. Since it is a multi output system, therefore the power is obtained in continues manner and thus the reliability of the plant is more as compared to other plants.

6. Suitable for distributed power.

7. Since the plant is set up in rural areas therefore side by side satisfying their power demands it is also promoting employment.

6.2 FUTURE SCOPE

Future scope of this cogeneration plant is very vast as it is totally dependent on renewable sources and moreover MHD generator used here has no mechanical intermediate i.e. electrical energy is directly obtained from heat energy.

Predicted future scope can be:-

a. This cogeneration plant can further be connected with smart grid for more benefits.

b. TEG can be exchanged with other renewable source in cogeneration so as to make the plant more reliable.

c. Power can be generated directly from Agri – residues.

d. At present vast research is going on MHD, so MHD itself is an area of research.

e. The plant can be made by using dynamic analysis as the transients which can be present in the linear model of the hybrid plant can be eliminated i.e. losses and power transmission problems can be tackled.