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DECENTRALIZED ENERGY SUPPLY POSSIBILITIES BASED ON BIOMASS

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Abstract

A possible solution to the energy supply in the future can be the increasing use of renewable energy sources. Significant increase in usage of biomass for energy supply can be achieved only by means of promoting small power rate biomass fired systems.

In these systems the efficiency of total energy supply can reach the value of 85–90%. For the above-mentioned demands and according to statements for biomass utilization two model systems have been worked out. These are planned systems which apply existing solutions, but some new equipments have to be developed which integrate some existing methods. Developing the construction of the above mentioned systems, our main aim was to reach reasonable installation cost at high total energy utilization ratio. The electricity generation possibility is important, but the efficiency of electricity generation itself is not considered all-important. The turbine is one of the most important equipment which reduces the pressure of steam, meanwhile gives mechanical power at the turbine shaft. The applied equipment has plain and robust construction, which can be produced in serial production, and can be operated with little maintenance and without permanent attendance. The turbine which suits the above-mentioned demands best is the multiple disk type bladeless turbine.

The construction of this turbine makes it suitable for the above-mentioned purposes.

The investigated two systems can be applied in both well developed urban and less developed rural areas. The application of these types of systems will help to develop a sustainable energy supply system, and reduce environmental pollution.

Keywords: small scale co-generation, biomass firing, renewable energy, multiple disk turbine.

1. Introduction

In order to give a proper and comprehensive view about the above-mentioned topic, a short summary is needed on the present state of the energy supply field.

Energy supply has been an ongoing critical issue of our age. It is the industrial sector which hinders the ecological equilibrium most.

We all agree that the ecological system of the Earth has to be protected, or even we have to aim at restoring a previous ecological state. However, we do not intend to give up using the equipment which not only makes our life comfortable but at the same time needs more or less energy; should it be heat or in the form of mechanical or electric power.

It is essential to work out a system promoting a sustainable energy supply, which ensures the balance of the Earth's ecosystem in the long run.

While the energy consumption in developed countries stagnates or slowly increases, a rapid growth in energy consumption is to be expected in developing countries. By the middle of the next century the energy consumption of the world will have been doubled.

Preserving our planet's ecological system calls for the reduction of the fossil fuel consumption, which, in turn, will result in a reduced CO_2 emission. CO_2 is one of those materials which causes greenhouse effect and contributes to the global warming process. Our fossil-fuel resources are expected to hold out for a prolonged period, which can be attributed to the introduction of more efficient new technologies and the exploration of new fields.

As a result, the price for fossil fuels will increase at a slower rate than it was projected earlier. Consequently, the market itself does not stimulate properly the energy sector to step up their research and development activities aimed at the use of renewable energy resources and the exploitation of their results.

Nuclear energy does not produce CO_2, so it could have been a real alternative solution. However, it poses a continuous radioactive pollution risk to the environment and there are difficulties in finding appropriate storage place for radioactive waste materials. Due to these two factors, the proportion of nuclear power in energy generation cannot increase. A decreasing output is more likely in future because the public opinion goes against nuclear power all over the world.

A possible solution to this problem can be the increasing use of renewable energy sources. The European Union is going to increase the share of renewable energy sources from the current 6% to 12% in 2010.

2. Renewable Energy Sources (RES)

Renewable energy source means the type of energy source, which has not been accumulated over a long period of time, so it is not a fossil fuel. On the one hand, RES, e.g. solar, wind, wave or geothermal energy, replenish themselves naturally, making themselves available continuously or from time to time, or, on the other hand, they can be reproduced in one or a few years' period. This second group is called biomass, which means vegetable or animal materials.

In the first group, energy is available directly in the form of heat or mechanical energy. But in the case of solar or wind energy availability is not continuous, but varies subject to change in weather, season and part of the day conditions. Furthermore, the geographical situation has effects on intensity as well. In the case of geothermal or wave energy, availability is localized.

In the case of biomass, energy is stored in chemical bonds. Materials can be delivered and stored, so production and utilization can be separated.

Gaining energy from biomass is realized by means of burning it. This happens in the same way as in the case of fossil fuels. Burning of biomass also produces

CO_2, but plants in their growing stages absorb large amounts of CO_2, that is why the burning of biomass is neutral from the viewpoint of CO_2 balance of the world. Furthermore, when biomass decomposes, it produces the same amounts of CO_2 in longer term. The volume of other pollutants produced by burning, such as CO, NO_x, flying ash, soot can be reduced to minimum values by means of installing up-to-date firing equipment and cleaning systems.

So it is much better and more environment-friendly to burn biomass waste than let it rot.

An increasing use of biomass in energy supply is driven by the overproduction of food-products in developed countries. So as to avoid overproduction, larger and larger agricultural areas have to be relieved of food production. Without another type of utilization this can cause considerable high unemployment in agriculture. From the ecological viewpoint, letting weeds growing in fallow lands cannot be regarded as a good and viable solution. By growing plants or woods with the aim of utilization for energy supply these problems can be avoided. Biomass powered energy supply can be spread based on these energy-woods or energy-plantations. The harvesting of energy-woods can be done continuously according to demands. As a result, it is not necessary to store a large amounts of timber for a long time.

Cereals, reed, maize, potato, etc. are also suitable for generating energy supply. But the harvest of these plants can be done only once or twice a year, so it is seasonal. During the harvest there is large demand for human and machine resources, which are unutilized in the rest of the year. Furthermore, large storage capacity is needed until using up.

The dimension range of biomass is large, which makes the manipulation of materials difficult. Therefore size homogenization processes have to be applied, (e.g.: chipping or briquette forming), which processes are characterized by considerable energy consumption. Furthermore, they have low pile density (bulk density), which results in demand for large delivery and storage volumes.

3. Using up Biomass as Energy Source

Ways of biomass utilization to generate energy can be divided into two groups.

1. In the first case the aim is to produce a refined fuel, which can be used up in existing equipment constructed to run on fossil fuel (e.g.: boilers, internal combustion engines, gas turbines). Original equipment needs to be either partly modified or remains unchanged. Forms of refined fuels from biomass:

   - alcohol (methanol, ethyl alcohol), from cereals, potato, sugar cane, etc.
   - vegetable-oil (bio-diesel) from sunflower-seed, rape or soya, etc.
   - bio-gas, wood gas from timber, cereals, cane, etc.

   Refinement of different raw materials needs more or less energy. Furthermore, refined fuel does not represent the total energy content of the raw

material. For utilization in engines or turbines further mechanical or chemical treatment is needed (e.g. esterification (esterification?) of bio-diesel, filtering out the tar from wood-gas, separation of incombustible parts from biogas and stabilization of heating value, etc.) These processes require further equipment and energy.
For driving vehicles only these refined fuel types can be applied. But for heat supply and electricity generation purposes this method does not seem to be optimal, not even if with the burning of refined fuels in IC-engines or gas-turbines the efficiency of electricity generation would be comparatively high.

2. It the second case bio-fuel is used with only a few modifications in solid form. This happens in special equipment, which is developed directly to this purpose. In this case it is the firing equipment that gets adjusted to burn the fuel and not the fuel to fit the equipment.

4. Features of Bio-Fuels

The ash content of biomass fuels is very low. There is little difference among the analysis data of dry parts of bio-fuels. However, the water content is high and can vary in a wide range in every case. This water content is not constant. It changes during storage or treatment. After harvest the biomass has a relatively high water content. During storage it is getting drier and drier. Its water content has a considerable effect on the heating value and firing behaviour. It is worth noting that the volatile content of bio-fuels is high, which produces long flame. Therefore a relatively high fire-chamber volume is needed to ensure proper burning out. The ash content of bio-fuels is low, but there is great difference between the ash behavior of different bio-fuels. For example wood-ash is white-gray, flour-like and does not melt even at high temperature. But the ash of straw melts at about 850 °C, becomes glass-like and can stick to different parts of the fire chamber rendering it unusable. Because of the wide range of chemical combinations, and the eutectic effects of different compounds, the ultimate analysis of ash does not give any relevant information about ash properties.

Traditional firing equipment made for coal burning application can only be adopted to biomass firing to a limited extent.

Mainly the size and humidity content of bio-fuel determine the firing method of biomass. A universal, all-purpose firing equipment suitable for every type of bio-fuels cannot be manufactured due to their wide range property variation. The size range and humidity content determine firing properties and suitable firing equipment constructions where it can be burnt properly.

From the viewpoint of combustion it is considered the best when size and quality variation of the bio-fuel is in a narrow range. The wider the range is, the more difficult it becomes to burn properly, and to ensure a low pollutant emission level. But homogenization of bio-fuels needs further equipment and results in energy consumption, which ultimately reduces the total efficiency of energy production.

The energy demand of these processes can reach or even exceed 10% of the total energy represented by bio-fuels.

From the viewpoint of energy production, the best way is when bio-fuels can be burnt with no or only a few treatments. But efficiency and pollutant emission demands have been becoming stricter and stricter nowadays. So as to satisfy these requirements, bio-fuels have to be homogenized up to a certain level in every case.

5. Co-generation Possibilities Based on Biomass

Biomass as an energy resource can be used up at different scales ranging from home usage up to large power stations. It was investigated how the biomass can be used at different power levels.

Below we present the investigation data from four different cases of energy generation based on biomass which were as follows:

1. Home energy supply system
2. Industrial or communal energy supply centre
3. Heat supply power station
4. Basic power station

Table 1 shows power and efficiency data for different systems. Yearly fuel consumption and storage data are calculated assuming an average utilization rate of 50%.

The energy content of biomass is relatively low and a considerably high area is necessary for growing wood or other type of plants. In case of large power stations the bio-fuel production requires very large areas. As a result, transport costs of bio-fuel can be considerably high. Moreover, the energy supply for transport is generally based on fossil fuels, exactly that energy source which we intend to replace with biomass. So the total energy production efficiency of large power stations significantly falls due to the above-mentioned facts.

The higher the nominal power of a power station, the higher the efficiency of electricity generation can be.

But the utilization of condensation heat is more difficult when a system has higher power. Moreover, a large heat supply network is characterized by high heat loss, which reduces significantly the efficiency related to end user heat demand.

So the possibilities of setting up large power stations fired with biomass are limited.

Significant increase in usage of biomass for energy supply can be achieved only by means of promoting small power rate biomass fired systems.

In these systems the efficiency of total energy supply can reach the value of 85–90%. Benefits of disperse energy supply centres:

- It is not necessary to invest in large power stations and transmission systems.
- Biomass fuel does not need to be delivered over long distances.

Table 1.

	1. Home energy supply system	2. Industrial or communal energy supply center	3. Heat supply power station	4. Condensing power station
Applied power	60 kW	1.18 MW	111 MW	444 MW
Available calorific output	50 kW	1 MW	100 MW	400 MW
Available electricity power	1.8 kW	40 kW	35 MW	200 MW
Efficiency of electricity generation	3.6%	4%	35%	50%
Efficiency of total energy utilization	85%	85%	60%	50%
Yearly power and consumption data at 50% average utilization rate:				
Heat equivalent of consumed fuel:	0.95 TJ	18.5 TJ	1750 TJ	7007 TJ
Consumed timber	120 t	2320 t	218720 t	875920 t
Pile volume of consumed timber	480 m^3	9280 m^3	874872 m^3	3503680 m^3
Necessary firewood-yielding forest area	6 ha	116 ha	10936 ha	43796 ha

- Avoidance of loss by heat and electricity transmission at distribution networks.

So the end user efficiency of energy utilization at small scale is certainly higher than in case of energy supply from large power stations.

6. Biomass Fired Mini Power Stations

For the above-mentioned demands and according to statements for biomass utilization two model systems have been worked out. These are planned systems which apply existing solutions, but some new equipment has to be developed which integrates some existing methods.

Both systems are operated with saturated steam as a working medium, and condensation heat is utilized at backpressure side. Because of the low pressure level, cycle efficiency of the Rankine-cycle is at about 10%, and the efficiency of electricity generation is under 5%. But the total energy utilization efficiency can be kept at about 85% because of condensation heat utilization at backpressure side. Since the pressure level is low, components of the system can be manufactured or purchased at low cost.

These two systems are the first and second ones from the above detailed table:

1. Home energy supply system
2. Industrial or communal energy supply center

Description of these two systems and scope of applications:

1. Home Energy Supply System

This system is suitable for the energy supply of a detached or a semi-detached house.

Nominal data of the system:

Fuel:	logwood
Fuel consumption:	$\approx$ 20 kg/h (storage capacity $\approx$ 0.04 m^3/h)
Output heating capacity:	46 kW (output temperature $t = 120\,^\circ$C)
or	
Output cooling capacity:	15 kW (e.g. air conditioning)
Output electric power:	1 kW (3400 V/50 Hz)

Electricity generation can be provided either connected to the main supply system or independently. *Fig. 1* shows the built up of the system.

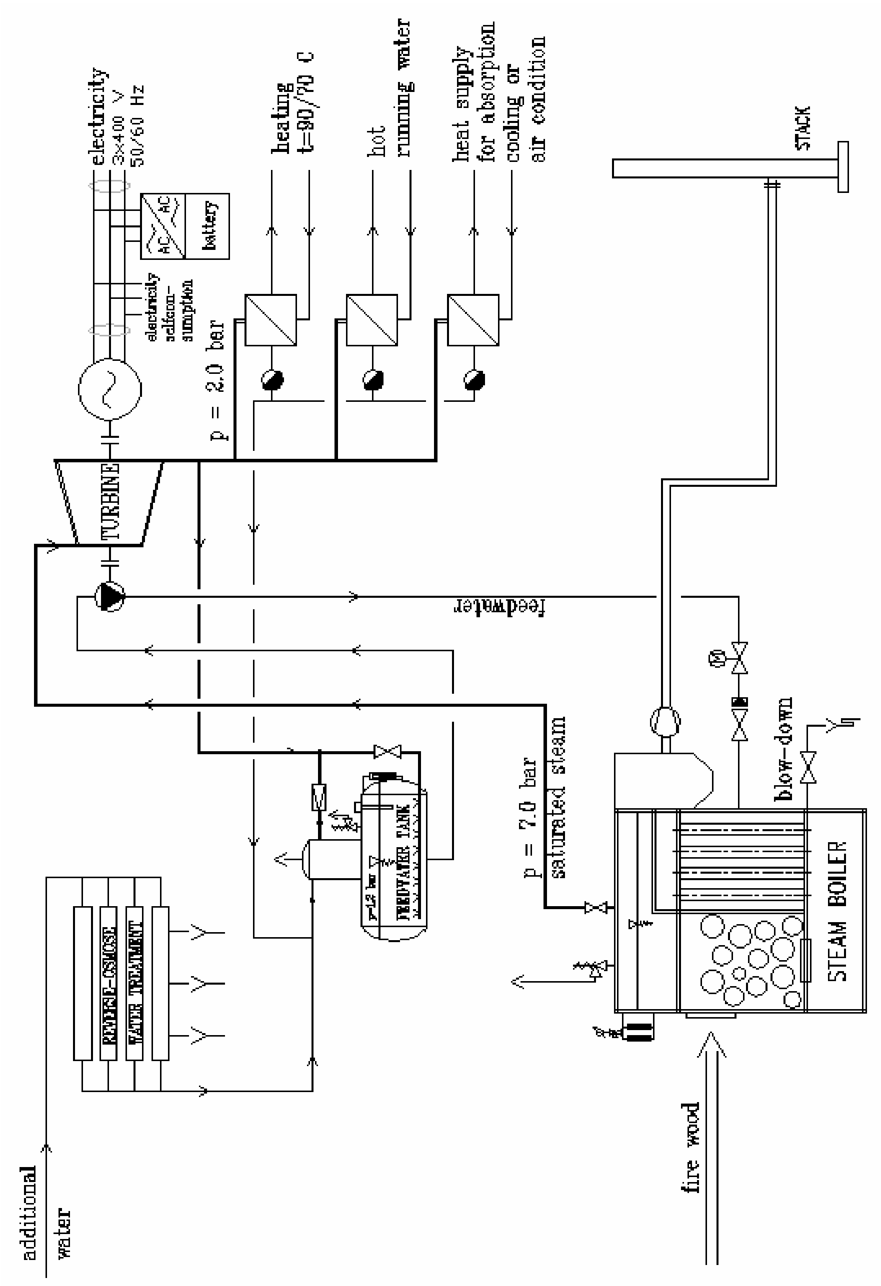
2. Industrial or Communal Energy Supply Center

This energy supply center is suitable for a small industrial or agricultural plant, or for a small block of flats, or public buildings, e.g. school, hospital, etc.

Nominal data of the system:

Fuel:	chips from wood or other agricultural wastes or saw-dust
Fuel consumption:	$\approx 350 - 400$ kg/h (storage capacity in case of wood chips $\approx$ 1 m^3/h)
Output heating capacity:	915 kW (output temperature $t = 120\,^\circ$C)
or	
Output cooling capacity:	300 kW (e.g. air conditioning or techn. cooling)
Output electric power:	26 kW (3×400 V/50 Hz)

Electricity generation can happen either in connection to the main supply system or independently. *Fig. 2* shows the built up of the system.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3×400 V
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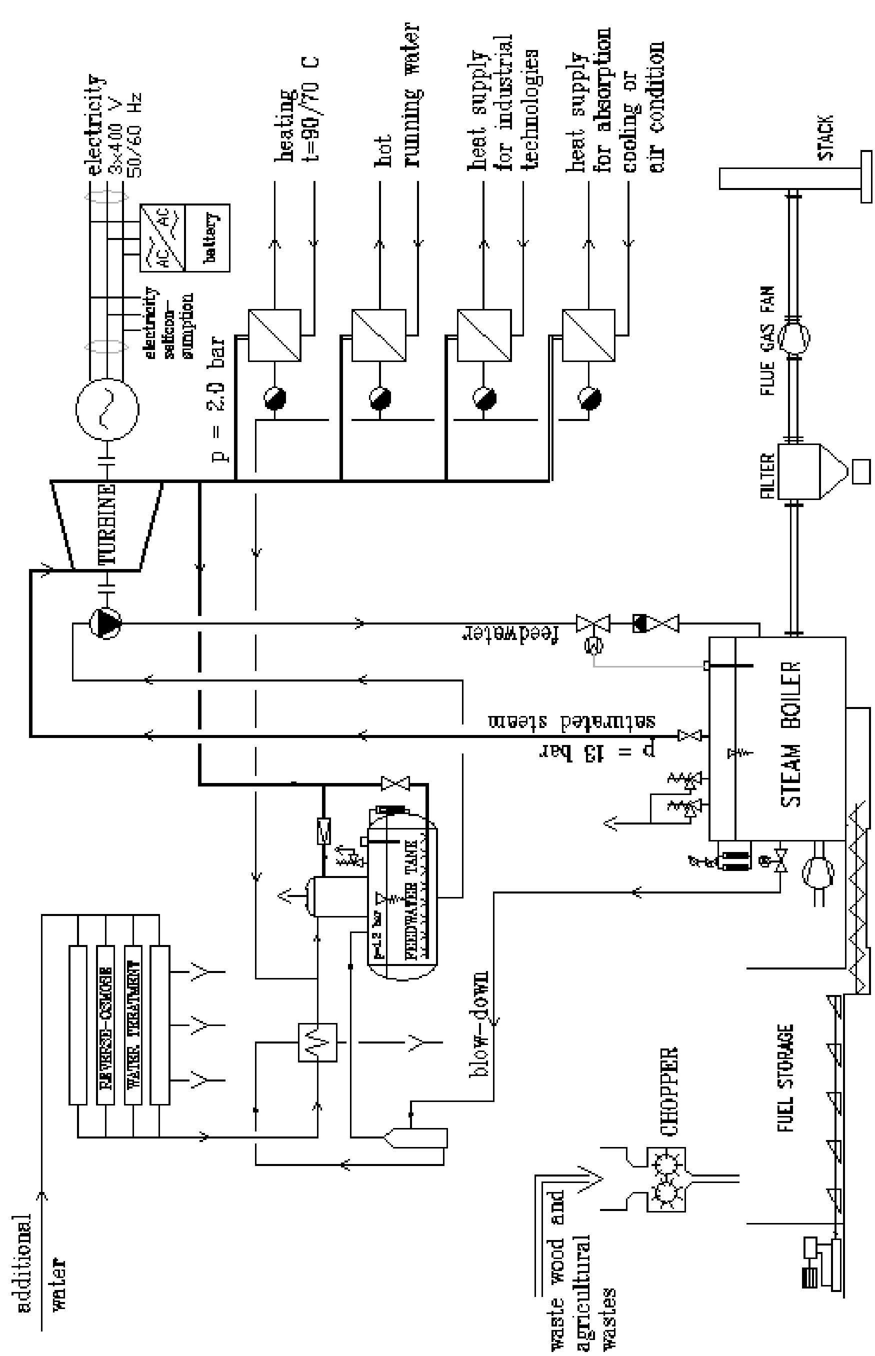
p = 2.0 bar
heating
t=90/70 C
hot
running water
heat supply
for absorption
cooling or
air condition
STACK
TURBINE
feedwater
p = 7.0 bar
saturated steam
blow-down
FEEDWATER TANK
REVERSE-OSMOSE
WATER TREATMENT
STEAM BOILER
additional
water
fire wood

Fig. 1.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FILTER
TURBINE
p = 2.0 bar
feedwater
saturated steam
p = 13 bar
STEAM BOILER
p=1.2 bar
FEEDWATER TANK
REVERSE-OSMOSE
WATER TREATMENT
blow-down
additional
water
waste wood and
agricultural
wastes
CHOPPER
FUEL STORAGE

Fig. 2.

7. Description of System Components

7.1. Fuel Preparation and Storage

1. System:

Preparation: Wood has to be cut into pieces which fit for the storage tank of the boiler. Maximal size is at about 5–60 cm.

Storage: Fire-wood shall be stored in roofed area, so as to help the drying process of wood, and to avoid freezing in winter time due to snow. Required storage capacity for one-month operation:
At 100% utilization rate: 30 m^3
At 60% utilization rate: 18 m^3

Fuel feed: Manual feed of the storage tank of the boiler, once or twice a day.

2. System:

Preparation: Wood or agricultural waste has to be chopped to the maximal size of 50 mm. Fuel has to be purchased in chips form, or an own chopper has to be applied. Sawdust or shavings from timber industry can be fired directly without any further treatment.

Storage: Firewood shall be stored in roofed area, so as to help drying process of wood, and in order to avoid its freezing in wintertime due to snow. At the selection of delivery and storage components adhesion and cohesion properties of the fuel have to be taken into account, in order to avoid vaulting. Required storage capacity for one-month operation:
At 100% utilization rate: 750 m^3
At 60% utilization rate: 450 m^3

Fuel feed: Manipulation and feed are performed by means of an automatic feeding system.

7.2. Boiler

1. System:

Wood-gasifying steam generator.

Wood will be gasified because of heating, and fuel will be burnt in gas form. Burning power can be adjusted with the air quantity control. It can be operated even at 30% part-load. In order to ensure continuous low emission and high efficiency, air quantity can be controlled by an O_2 sensor in the flue gas. These types of boilers are series produced for hot water heating systems. This firing system is suitable for us when fitted with a heat exchanger part to generate saturated steam.

The boiler is equipped with an internal cyclone type flying ash filter.

Nominal data of the boiler:

Heating capacity:	50 kW
Steam capacity:	75 kg/h
Steam pressure:	7 bars
Steam temperature:	saturation temperature (165 °C)

2. System:

Steam generator with underfeed stoker type firing equipment.

Wood-chips or sawdust is fed with feed-screw. This firing system is suitable for agricultural waste material firing as well. Fire chamber is covered with fireproof arch. This helps the drying and for ignition of the fuel. So fuels with high water content can be burnt properly. Burning power can be adjusted with the air quantity control. It can be operated even at 30% part-load. In order to ensure continuous low emission and high efficiency, air quantity can be controlled by an O_2 sensor in the flue gas. Low fire chamber temperature results in low NO_X emission. After the boiler a flying ash filter has to be installed.

Nominal data of the boiler:

Heating capacity:	1 MW
Steam capacity:	1500 kg/h
Steam pressure:	13 bar
Steam temperature:	saturation temperature (192 °C)

7.3. Turbine-Generator Set

The turbine is the equipment which reduces the pressure of steam, meanwhile gives mechanical power at the turbine shaft.

Demands on applied turbines:

- It shall be suitable for operation within a wide range of steam parameters.
- It shall be fit to operate with saturated steam.
- It needs a plain and robust construction
- It shall require little maintenance
- The price of the turbine shall be reasonable
- High efficiency is not a strict demand, because the condensation heat after the turbine is utilized.

The turbine which suits the above-mentioned demands best is the multiple disk type bladeless turbine. The construction of this turbine makes it suitable for above-mentioned purposes.

7.4. Basic Principles of the Turbine

The built up of this turbine is very similar to that of a centripetal turbine. It has got a nozzle which accelerates the working medium to high speed. The best working condition can be obtained when the nozzle outlet velocity is at about sonic speed. This working medium is streaming into the rotor in a nearly tangential direction..

The rotor does not have any blade and for this very reason this construction is called ‘bladeless turbine’. The rotor is built up from smooth parallel disks, that is why it is also referred to as ‘multiple disk turbine’.

The high speed working medium is streaming between parallel rotating disks, meanwhile energy transformation happens by means of boundary layer friction. Because the fluid flow is parallel with the disks, there is no stream collision with blades under any operational conditions.

Owing to these features, this turbine can be efficiently applied at a wide range of working medium parameters.

Fig. 3 shows the basic operational principle of a multiple disk turbine.

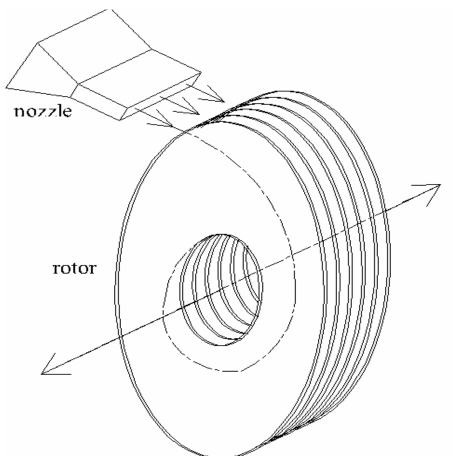

Fig. 3.

Advantages of this type of turbines:

- This type of turbines can be adjusted to different circumstances by applying a few modifications. Only the nozzle cross section has to be adjusted to the actual demand, which is an interchangeable part of the equipment.
- The turbine operation control can be performed directly at the nozzle by means of the adjustable nozzle cross section. The continuous variation of nozzle cross section gives efficient power control via mass flow rate variation at the same pressure drop. In this way throttling process can be avoided in the whole control range. In this way turbine efficiency can be kept at about the nominal value even in part load. The *Fig. 4* shows efficiency variation against relative mass flow rate.

- This type of equipment can be operated at a wide range of working medium parameters without any danger of erosion or malfunction.
- It is not sensitive to a partially polluted working medium, since the fluid flow is parallel with disks, so it can be operated even with saturated steam.
- Because of its plain construction, the manufacturing cost will be kept comparatively low.
- The same base-construction can be used for wide power and working medium parameter range. Only the nozzle has to be adjusted to actual situation. That is why it can be produced in serial production.

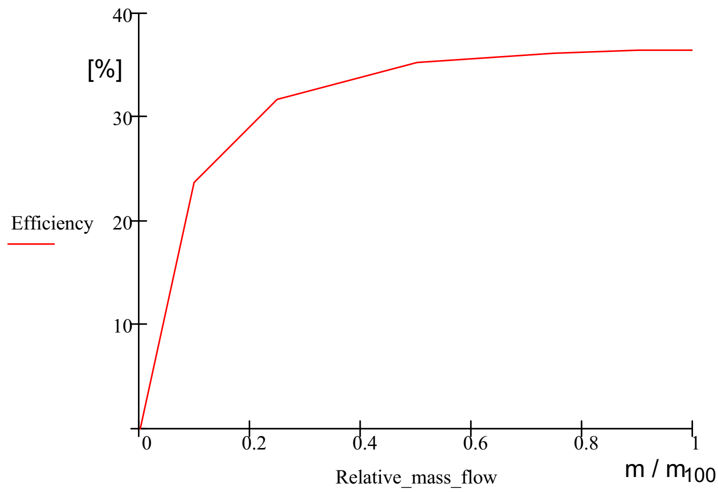

Fig. 4.

Drawbacks:

- Efficiency of these types of turbines is relatively low; it is at about 30–40%.

Fig. 5 shows efficiency variation against speed ratio.
The optimal speed of the turbine is at about: $u/c_s = 0.41$
(u – peripheral speed)
(c_s – sonic speed)

With low-capacity equipment this results in a relatively high revolution speed.
Fig. 6 shows efficiency variation against pressure ratio, $\varepsilon = p_{out}/p_{in}$.

The minimum applicable pressure ratio is at about $\varepsilon = 0.2$ When larger pressure drop has to be utilized, more stages are needed. Relatively low efficiency does not ruin the total efficiency of the system, because of heat utilization at backpressure side. Furthermore, as for the saturated steam inlet to the turbine, outlet steam will not contain large amount of water. So applying the multiple disk turbine for low power rate systems grants us a solution which cannot be matched by any other type

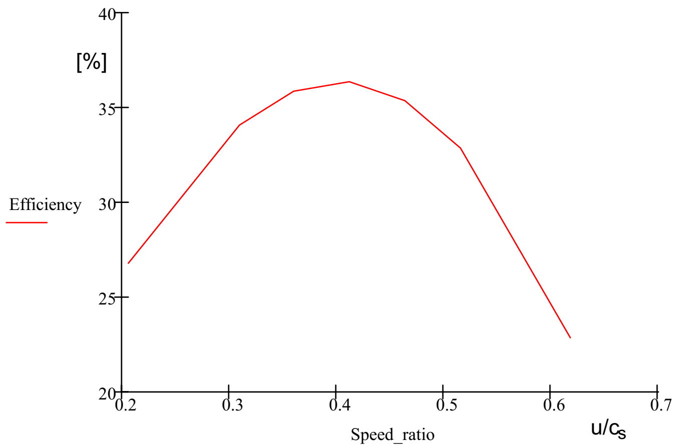

Fig. 5.

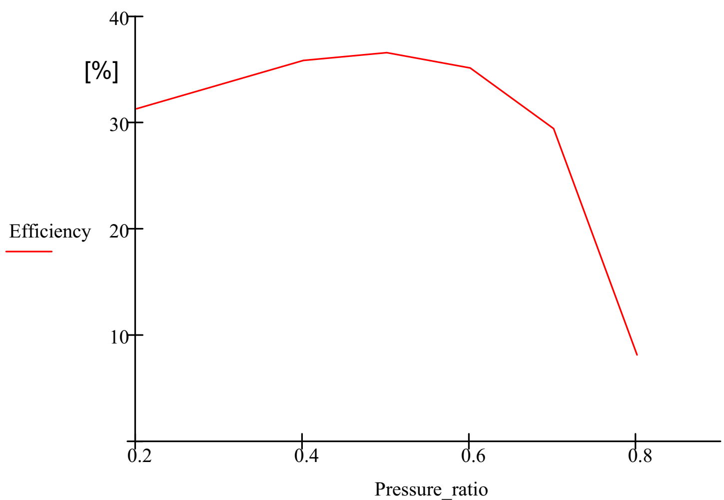

Fig. 6.

of bladed turbines. The nominal data of the turbines required for our two systems can be seen in *Table* 2.

This turbine drives on the one hand the alternator, and on the other hand the feed-pump directly. The alternator is connected directly to the turbine, without any gear-box. So the applied alternator has to be a high speed alternator. It generates current at high frequency. Network synchronization is realized through an AC/AC converter. This system ensures electronically adequate frequency and voltage level. The controlling system operates in close cooperation with the AC/AC converter and

Table 2.

	1. System	2. System
Inlet pressure:	7 bar	13 bar
Outlet pressure:	2 bar	
Mass flow rate of steam:	75 kg/h	1500 kg/h
Nominal power:	1.8 kW	40 kW

is installed into the same electronic-box.

When the system is operated in stand-alone mode, a certain battery storage capacity is needed for balancing fast current demand variation, and for starting-up the system.

8. Condensation Heat Utilization at Backpressure Side

Heat supply is provided by means of saturated steam with 2 bar pressure. Saturation temperature corresponding to this pressure value is $t_s = 120$ °C. This is suitable for the most of heat demands. Possible heat utilization forms can be:

- Room heating
- Hot running water production
- Heat supply for industrial technologies
- Cooling with heat by means of an absorption cooling system, for air-conditioning or industrial cooling.

Heat supply is provided by means of heat exchangers. Condensed water is fed back to the feed-tank.

Nominal data of heat supply:

	1. System	2. System
Total capacity:	50 kW	1000 kW
Total mechanical power:	−1.8 kW	−40 kW
Self heat consumption:	−3.2 kW	−45 kW
Output heat capacity:	**45 kW**	**915 kW**
In case of absorption cooling		
Output cooling capacity:	**15 kW**	**300 kW**

9. Electricity Generation

In order to reach high total efficiency, the power control of the system runs according to the variation of heat demands, generated electric power is the function of the heat demand variation. The generated electricity can be utilized through utility mains or independently. In the case of the independent operational mode, a battery system is needed for smoothing the variations in electricity demands.

Nominal data of electricity generation:

	1. System	2. System
Total mechanical power:	1.8 kW	40 kW
Driving power of feed-pump:	0.3 kW	4 kW
Generated electric power:	1.5 kW	36 kW
Self electricity consumption of the system:	0.5 kW	10 kW
Output electric power:	**1.0 kW**	**26 kW**

10. Feed Water and Condense Water System

Return quantity of condensed water is more than 90%, since the condensed water system is closed. Some water loss arises at degassing tower and during the processes of slagging or desalination of the boiler.

Needed degassing feed-tank volume:

1. System: 0.25 m^3
2. System: 3.0 m^3

Water quantity compensation is solved by means of a water treatment system, which operates according to the reverse osmoses principle.

Nominal data of water treatment systems:

	1. System	2. System
Nominal water flow:	20.0 l/h	300 l/h
Average water flow:	7.5 l/h	150 l/h

11. Control

The operation of the system is controlled electronically. It is fitted with all the necessary equipment to ensure continuous operation without permanent attendance.

12. Annual Heat and Electricity Generation and CO_2 Emission Reduction

Table 3 shows summarized data of annual heat and electricity generation and CO_2 emission reduction in case of 50% average utilization rate.

Table 3.

	1. System	2. System
Useful heat quantity	725 GJ/year	14400 GJ/year
Output electricity	4400 kWh/year = 16 GJ/year	114000 kWh/year = 410 GJ/year
CO_2 emission reduction instead of natural gas usage	49.34 t/year	988.38 t/year
CO_2 emission reduction instead of fuel-oil usage	62.73 t/year	1256.65 t/year

13. Summary

The European Union is going to increase the share of renewable energy sources from the present 6% to 12% in 2010. Installation of large power stations based on biomass is limited. Significantly increasing use of renewable energy sources can only be reached when the above mentioned low power rate systems are included and widely spread. In this case, biomass should not be collected from over a large area and delivered over long distances. Furthermore, it will help to reutilize large areas which already had to be removed from food production.

Developing the construction of the above mentioned systems, our main aim was to reach reasonable installation cost at high total energy utilization ratio. Furthermore, the electricity generation possibility is important, but the efficiency of electricity generation itself not considered all-important.

That is why equipment with plain and robust construction were selected, which can be produced in serial production, and can be operated with little maintenance and without permanent attendance. The above described two systems can be applied in both well developed urban and less developed rural areas. The application of these types of systems will help to develop a sustainable energy supply system, and reduce environmental pollution.

Working in conjunction with our industrial partners, our organizations are going to realize these systems in demonstration projects. We would like to apply for national and European support for the realisation of these systems.

So as to help fast spread of these types of systems several incentives (e.g.: VAT refund, subsidy, preferential credit, etc.) were needed. Benefits would be experienced at both private and national economy levels.

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