RESEARCH CENTER OF
NEW AND RENEWABLE ENERGY

INSTITUTE TECHNOLOGY BANDUNG
(ITB)

VISION

Center of New and Renewable Energy Advance in Indonesia.

MISSIONS

1. Synergize the potential of ITB researches in generating new and renewable energy technologies.
2. Provide direction of development of new and renewable energy technologies in Indonesia.
3. Generate and provide the real technology of the new and renewable energy for Indonesian benefit.

RESEARCH FOCUS

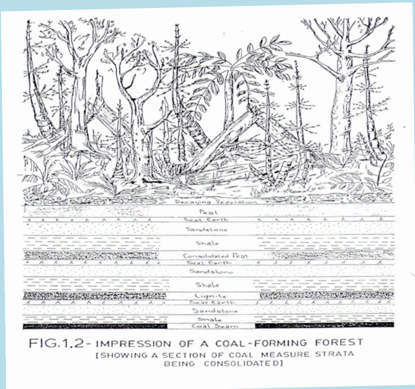
- Hydro and Wind Turbine
- Organic Rankine Cycle
- Biomass
- Coal Upgrading
- Photo voltaic
- Bio Fuel
- Geothermal Technologies
- Smart Grid

UPGRADING OF THE SEQUESTERED CARBON IN TO THE PLANTS AS SOLID FUEL FOR ALTERNATIVE ENERGY RESOURCE

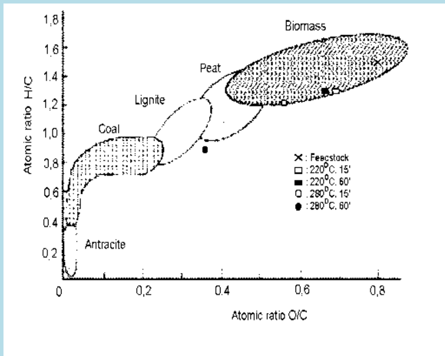
All the tropical countries, including Indonesia, are considered to be the place where the most of CO_2 sequestered into the plants. Carbon sequestration processes:

1. Started when the plants died, buried, and became rotten.
2. Natural heating process and soil pressure for a long time

Became coals with the grades: anthracite, bituminous, sub-bituminous, and lignite (depend on their ages). Peat; not completed yet coalification process and have characters similar as the woods. Biomass such as woods, leafs and trashes including the MSW (municipal solid waste), considered as the renewable energy sources.



Process mechanism of sequestered carbon from the plants to coal.

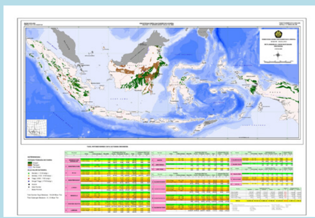


O/C and H/C content of coal, peat, and biomass

Low Rank Coal Upgrading

Background

- Indonesian coal deposit: 104 billions tons
- Major location: Sumatra and Kalimantan.
- 70% of coal deposit: low rank coal (LRC), mainly lignite and sub-bituminous.



Location of coal mines in Indonesia

Laboratory scale LRC upgrading research (1994)

- Coal Upgrading Technology (CUT) Method
- Double Effect Continuous Drying Method
- Production capacity: 100 kg/h
- Caloriefic Value increased from 4290 kcal/kg to 6700 kcal/kg


Lab scale experimental set up of LRC upgrading

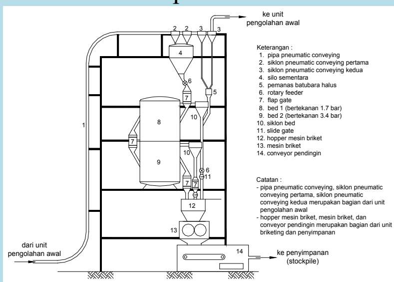
Pilot plant scale LRC upgrading development (2007)

- Location: Kalimantan
- Consists of the detail system and components design, erection of plant, commissioning, trial operation
- Intake capacity: 7 tons/hour


Pilot plant scale

Commercial scale LRC upgrading development

- Intake capacity: 150 ton/hour.

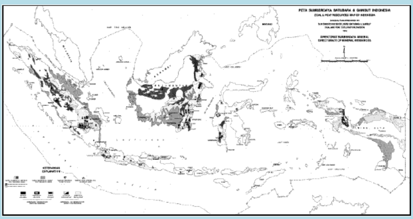


Commercial plant scheme

Peat Torrefaction

Background

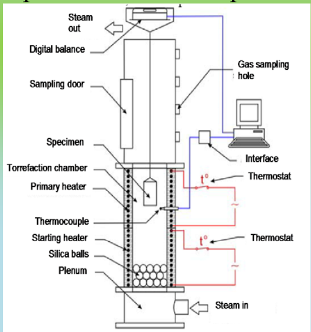
- Indonesian peat: third largest in the world
- Potential: 200 billions tons


Location of peat in Indonesia

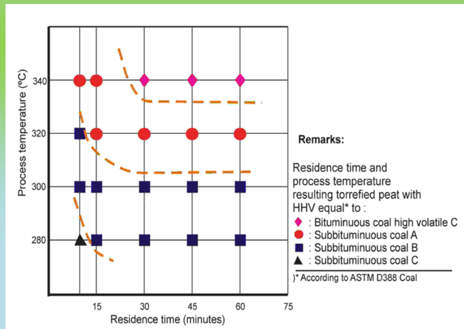
Peat torrefaction

- Torrefaction: thermo-chemical process of solid (fuel) to increase the heating value, by treatment at medium temperature in absence of oxygen condition, through limited devolatilisation
- Important parameters on torrefaction process: temperature and resident time
- Peat is partially or incompletely decomposed biomass, deposited together with complementary minerals.

Batch peat torrefaction experiment



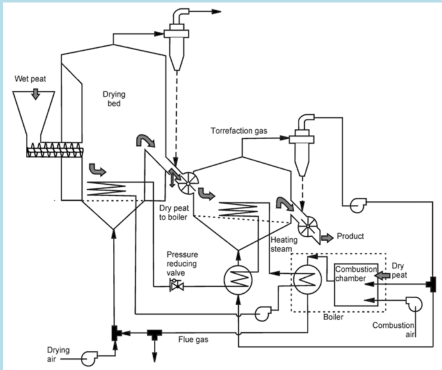
Batch torrefaction experiment schema



Peat torrefaction map

Continuous peat torrefaction development

- Raw material: 8kg/h, 50% MC
- Operating cond.: 300^{o}C, 30 minutes
- $HHV_{product}$: 5700kcal/kg



Torrefaction of Biomass

Background

- Indonesian biomass potential

Type of Biomass	Generation	Conversion Factor	RDF Potential
	(Million Ton/year)	(%)	(Million Ton/year)
Palm	40,4	23 – 50	9,3 - 20,2
Sugar cane	12,4		2,9 - 6,2
Rice	44,4		10,2 - 22,2
Coconut	8,3		1,9 - 4,1
Wood	2,4		0,5 - 1,2
Total	107,8		24,8 - 53,9

Calorie value of torrefaction product: 5,700 kcal/kg equivalent to subbituminous coal.

Torrefaction result

Before torrefaction

After torrefaction

Torrefaction of MSW

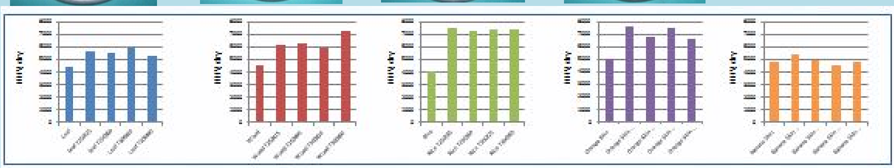
Background

- Municipal Solid Waste (MSW) production in several cities in Indonesia:

Cities	MSW production		Heat of Combustion	
	(m^3/day)	(ton/day)	Calorific Value (kkal/kg)	Equivalent (MW)
Jakarta	27966	6236	2500	755
Surabaya	8700	1940		235
Bandung	7500	1673		202
Medan	3973	886		107
Total	**48139**	**10735**		**1300**





Calorie value of torrefaction product: 6000 kcal/kg equivalent to subbituminous coal.

Conclusion

- Several upgrading process done to substances formed from believed sequestered CO2 are discussed.
- The substances are usually in forms of complex chemical compound that already mixed with other impurity such as H2O and other non-combustible substances.
- The upgrading process basically is to remove these impurity and to discompose those complex compound to more samples one, done by thermal process such hydrothermal and torrefaction process.

LOW-ENERGY CONSUMPTION BUILDING BY USING HIGH-EFFICIENCY BUILDING INTEGRATED PHOTO VOLTAIC (BIPV)

One problem on PV application is reduction of PV efficiency by temperature. The rise in temperature on the PV surface reduces the energy conversion efficiency of 0.4% - 0.5% every increase of 1 K. Reduction efficiency starts from 25^{o}C until 80^{o}C. Several ways have been done to reduce the surface temperature rise of PV, for example active cooling with air flow on the lower surface of PV. Water is also used as the cooling fluid of PV. The use of Phase Change Material (PCM) as a coolant PV was performed using paraffins. Geometry and size of the PCM container influence its performance to absorb heat.

Materials that will be used as the PCMs for PV/PCM system must have certain quality or fulfill the requirement, which are:

1. The materials must have high latent heat and high thermal conductivity
2. The materials should have melting temperature in range of operation, could melt congruently and be chemically stable.
3. Low cost, non-toxic, and non-corrosives.

Palm oil, which is locally available in Indonesia, with a melting point of 33^{o}C, can be an alternative PCM to be installed on the PV. The melting point of palm oil is suitable with daily temperature in the country. In this experiment, PCM was inserted into Aluminum hollow bars. Those bars then are assembled in the lower part of the PV panel, so that some part of thermal energy from solar radiation could be absorbed by the PCM.

Testing is done outdoors. Two mono-crystal PV panels are located side by side. Each has a power output 50Wp. PV panels can be seen in Figures 1 & 2.

Figure 1. Installation of PV panels outdoor

Figure 2. Back part of PV panels. Left panel is equipped with Al containing PCM

One of PV panel using palm oil as phase change materials for 8.325 liters. Aluminium profiles are used as containment, with width 2:54 cm, height 3.81 cm, and length 52 cm. The amount is 18 pieces. Voltage and current measurement results obtained from the controler Tristar TS-45. While the temperature for the top and bottom surfaces of PV obtained from TC-08 Omega data logger.

The PV panel without PCM is always has higher temperature than solar PV with PCM (see Figure 3). Figure 4 shows power generated for the solar PV system with and without PCM. The figures show that power generated from solar PV with PCM is higher than that of solar PV without PCM.

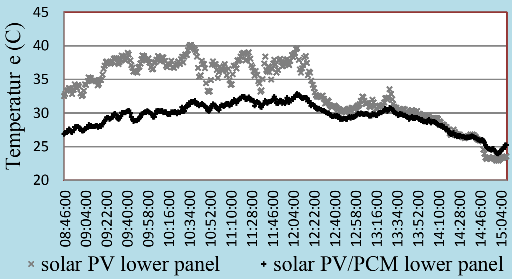


Figure 3. Lower PV panel temperature

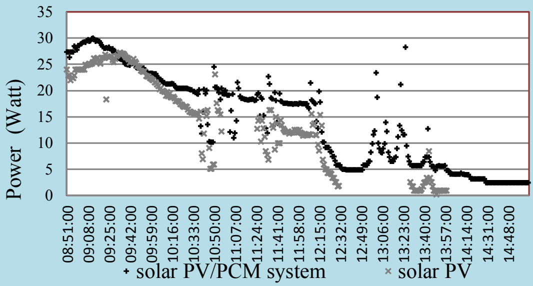


Figure 4. Power generated by solar PV with and without PCM

From the experiment result, PV with PCM shows lower temperature compared with PV without PCM, both at front and back part of PV panels. High latent heat of PCM is responsible for the phenomenon. Lower temperature of the PV panel then cause higher power produced by the panel. Average temperature reduction until noon time is 6.6^{o}C with corresponding power increase of 3.3 Watt.

DEVELOPING A MULTI-FUEL DIESEL ENGINE SYSTEM FOR INTEGRATED POWER GENERATION BASE ON RENEWABLE ENERGY

Currently and in the future it is need to develop local self-sufficiency of energy resources in isolated areas. Diesel engines genset system designed to use multi fuel included pure plant oil (PPO), biodiesel (FAME) and biogas as fuel and it is generated electricity which is can connecting to other renewable electricity such as solar and wind appropriate for that need. Today this type of diesel engine genset system is not available in the Indonesian market and still not yet manufactured also. There is a large market potential for this kind of diesel engine genset system.

The objective of this research is to made important component of a diesel engines which capable of utilizing multi fuel and design an inverter which can integrate with other renewable electricity that can be progressively produced within the country.

Manufacture of compatible connecting rod

The result of the first phase of research in the mechanical part was the connecting rod of the diesel engine. The connecting rod design was got from long research in "Riset Insentif" from 2010 - 2012 support by Ministry of Research. The last goal of the research is the product component can be compatible/interchangeable with other product. Because until today the domestic industry in Indonesia still have problem with made compatible/interchangeable product. The connecting rod products is shown in figure 1.

Figure 1. Two compatible/interchangeable connecting rods

Design of Single Phase Grid Connected Inverter using Power Variable

In grid-tied solar power systems, the grid-connected inverter is an essential part. This kind of inverter can regulate the power flow so that the photovoltaic cell can deliver its power to the electric network. The diagram in figure 2 can describe the whole system.

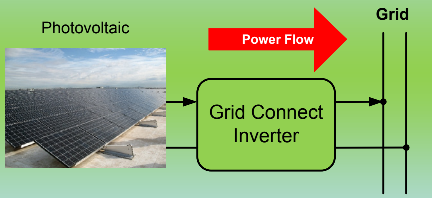


Figure 2. General diagram of a system with grid-connected inverter

In this research, a grid-connected inverter using power variable is developed. The power variable is easier to use in such photovoltaic–inverter system, so that the control can shift the operation point of the photovoltaic where it is needed. By using this technique, the bouncing problem in the zero-crossing detection in conventional inverter can be eliminated. The other advantage is that the inverter can also act as the power compensator to achieve unity or better power factor, as long as the power rating is still below the capacity of the inverter.

If a grid with voltage $(t) = V\sqrt{2}.\sin(\omega t)$, flowing a current $i(t) = I\sqrt{2}.\sin(\omega t)$, than the power delivered instantaneously would be $p = 2VI.(\sin(\omega t))^2 = VI - VI.\cos(2\omega t)$. The average value of $p(t)$is $P = VI$. The instantaneous current can be written as $i(t) = \frac{P}{V}\sqrt{2}.\sin(\omega t)$. All voltage and current variable V and I is stated in effective values.

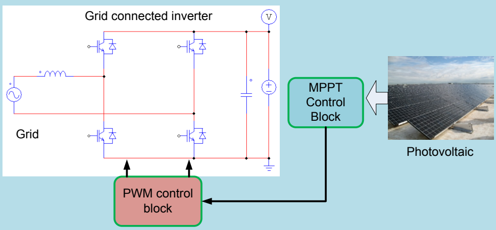


Figure 3. Implementation of the grid connected inverter

The implementation of the grid connected inverter can be shown in figure 3. The MPPT control block will force the operation point of the photovoltaic to work under the maximum power condition. The power command from the MPPT control block will be translated into the current reference for the PWM control block to regulate the current in the inverter.

The PSIM simulation result can be shown in Figure 4, where the current flowing in the ac side inverter will be 180^{o} of phase difference with the voltage. This means that there is power flowing from the dc side of the inverter to the grid.

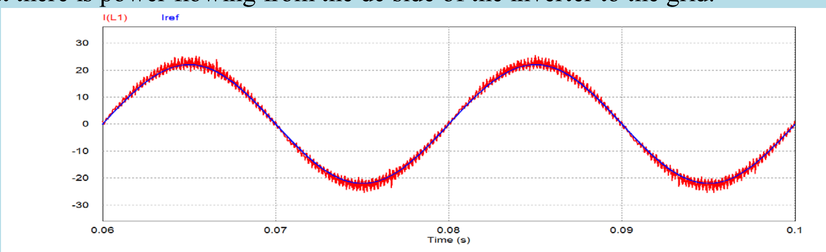


Figure 4. Current waveform of the ac side inverter, in-phase with voltage

SIMULTANEOUS TORREFACTION MODELLING OF MUNICIPAL SOLID WASTE (MSW) FOR HIGH CALORIFIC VALUE SOLID FUEL

Research about torrefaction of MSW has been conducted in ITB's Thermodynamics Laboratory. Result of previous research showed that torrefied MSW is potential enough as solid fuel alternatives due to its shown high calorific value. Therefore, torrefaction process is expected to be a solution for complicated problem between fuel and MSW crisis. Despite its shown potential, torrefaction still need some steps so that it can reach its realization as upgrading methods for MSW. Simultaneous torrefaction system is the simplest way to develop torrefaction system according to the heterogeneity of MSW in Indonesia. However, previous research still did not cover all of needed data for simultaneous torrefaction process. This research develops modeling of simultaneous torrefaction in an empirical equation in order to prediction can be performed for different composition of MSW components to reach the most effective simultaneous torrefaction process.

Empirical Formula of Temperature Prediction

From analysis that had been conducted, there was two feed parameter from individual torrefaction experiment, yielded mass relative and calorific value. Result shown calorific value test is prior to yielded mass result because calorific value of the product is the main purpose of this research. In addition, during experiment, calorimeter bomb has greater precision than torrefaction reactor. Based on performed analysis, empirical formulation were conducted to decide simultaneous torrefaction design and to predict HHV of simultaneous torrefaction products. Empirical formulation was designed using optimum temperatures references and the highest HHV combined with mass fraction of MSW components. The empirical equation is shown below:

$$T_{ts} = (300x_1 + 320x_2 + 215x_3 + 285x_4 + 320x_5)\ °C \quad (1)$$

Where:

Tts = Designed temperature of simultaneous torrefaction (°C)

x_1 = Mass fraction of Rice composition in MSW components (%)

x_2 = Mass fraction of Orange Peels composition in MSW components (%)

x_3 = Mass fraction of Banana Peels composition in MSW components (%)

x_4 = Mass fraction of Branches composition in MSW components (%)

x_5 = Mass fraction of Leaves composition in MSW components (%)

Simultaneous Torrefaction Modelling

HHV prediction for simultaneous torrefaction should be conducted by interpolating experiment HHV value in torrefaction temperature 295 °C for each

MSW components. Therefore, predicted HHV at the 295 ^oC simultaneous torrefaction temperature was written in the Equation 2.

$$HHV_{sk} = (5506x_1 + 6682x_2 + 4341x_3 + 5635x_4 + 6171x_5)\ {}^{kkal}/_{kg} \quad (2)$$

Where:

HHVst = Predicted HHV of simultaneous torrefaction product (kkal/kg)
x_1 = Mass fraction of Rice composition in MSW components (%)
x_2 = Mass fraction of Orange Peels composition in MSW components (%)
x_3 = Mass fraction of Banana Peels composition in MSW components (%)
x_4 = Mass fraction of Branches composition in MSW components (%)
x_5 = Mass fraction of Leaves composition in MSW components (%)

Design of Simultaneous Torrefaction

According to analytical equation which has been performed, Experiment need to be held to ensure that obtained analytical equation can be used as empirical equation. Consequently, simultaneous torrefaction experiment was conducted in the specific condition, shown Table I below. Simultaneous torrefaction was conducted for each composition models.

Table I: Modeling of Simultaneous Torrefaction Experiment

Torrefaction temperature	295^oC		
Resident time	45 menit		
Max. capacity of torrefaction reactor	30 gram (g)		
Composition			
MSW components	Model 1	Model 2	Model 3
Rice	5,7 g	7,5 g	9 g
Orange Peels	3,15 g	3,75 g	4,5 g
Banana Peels	3,15 g	3,75 g	4,5 g
Leaves	13,8 g	9 g	6 g
Branches	4,2 g	6 g	6 g

Result and Discussion

HHV of simultaneous torrefaction product was measured and compared to HHV obtained from analytical approaching. There are no significant differences of HHV in three models of MSW composition. Both analytical approach and experimental result showed same occasion. Due to the dominance of leaves in the MSW components, HHV result of simultaneous torrefaction had value slightly below leaves HHV at torrefaction temperature 295 ^oC.

Despite differences occurred, empirical formulation shown in Equation 1 and Equation 2 can be utilized to estimate temperature and HHV of MSW simultaneous torrefaction

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HHV of simultaneous torrefaction was compared to the HHV of commercial coal. The simultaneous torrefaction of MSW components has HHV value between Subbituminous Coal C and B.

DEVELOPMENT OF HOT BINDERLESS BRIQUETTING TECHNOLOGY FOR UPGRADED LOW RANK COAL

Coal resources in Indonesia are potential for oil substitute as the main fuel due to their abundance, but with current coal utilization technology only about one-third can be directly used while the rest is still classified as low rank coal (LRC, of lignite and subbituminous coal), having low sulfur content but high moisture content and low heating value; therefore its economical value is very low. The New and Renewable Energy Research Group ITB has been developing an upgrading process of LRC, with resulted product of dry coal powder which should be briquetted to overcome the transportation problem.

Conventional briquetting is employing binder in its process, usually clay or other material. These additional materials will increase the cost and reduce the calorific value of the product due to additional unburned components; therefore, in this research the study on hot binderless briquetting of Indonesian LRC was conducted. The original idea of this hot binderless briquetting process is that the binder will be supplied by the heavy Volatile Matters (VM) extracted from the coal itself. The combination of briquetting pressure, temperature and upgraded coal characteristics are studied experimentally.

The goal of the study is to obtain an optimum briquetting condition of upgraded low rank coal without using any binder. The result should become an alternative solution for low rank coal utilization in Indonesia. The research itself was in line with the cooperative research with Ishikawajima-harima Heavy Industries (IHI), where the company has developed a coal upgrading system but needed a subsequent briquetting process to support its transportation problem. After conducting literature study of the hot binderless briquetting process and identifying the character of low rank coal as alternative fuel, characterization of raw and upgraded coal such as proximate, ultimate analysis and calorific value were conducted with some results shown in table below.

Table 1. Low Rank Coal Characteristics and Particle Size Distribution Used in the Experiment

	Coal A	Coal B
Fixed Carbon (%)	37.44	36.99
Volatile Matter (%)	40.29	39.34
Total Moisture Content (%)	19.8	20.96
Ash (%)	5.58	5.85

Particle Size Distribution	Percentage (%)
710-2000 μm	15
354-710 μm	8
251-354 μm	21
125-251 μm	30
<125 μm	26

From the obtained information, a series of hot binderless briquetting experiments as shown in figure below were conducted with some boundary conditions of obtained products from the established IHI dryer. These included the moisture content, physical and chemical composition and particle size distribution of the upgraded coal. The experiment utilized an axial hydraulic piston as compression force for briquetting process, while for high temperature condition an electric heater jacketed briquetting dies was employed. The briquetted products were then underwent subsequent drop and reabsorptivity tests.

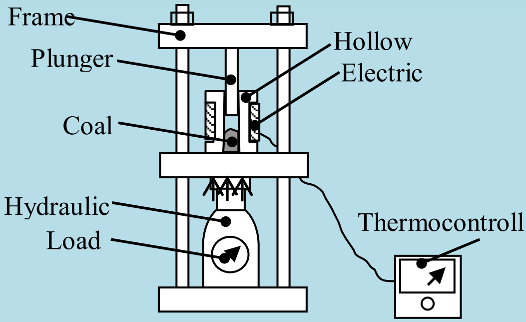


Fig. 1. Schematic diagram of axial hydraulic piston briquetting experiment.

Endurance of the produced briquette is obtained by performing a Drop Shatter Test where a Shatter Index (the percentage of >2 mm size particles after drop test) were calculated. From the figures below, it was found that certain briquetting pressure is greatly affecting the strength of the briquette. Another original finding is that the lower moisture content of product will produce lower briquette endurance.

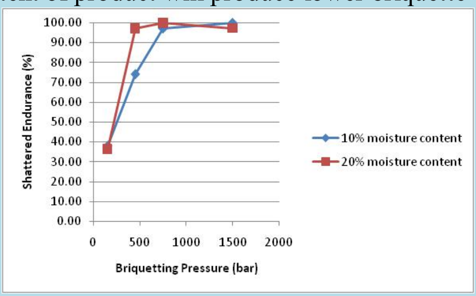


Fig. 2. Endurance of Coal A briquette products in accordance with its briquetting pressure.

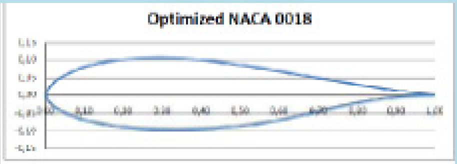
The obtained data, along with the reabsorptivity data are to be used as a start for designing a larger, commercial hot binderless briquetting system for upgraded low rank coal. It can be seen that after hot binderless briquetting process, the moisture of the briquetted product was reaching certain equilibrium after one month in ambient condition. It can be concluded that the briquette from this process is promising to be transported in long period.

EXPERIMENTAL OF THREE PARALEL WATER CURRENT TURBINE WITH OPTIMIZED STRAIGHT BLADES AND USING FLOW CONCENTRATOR CHANNELING DEVICE TO AUGMENTED PERFORMANCE AND SELF STARTING CAPABILITY

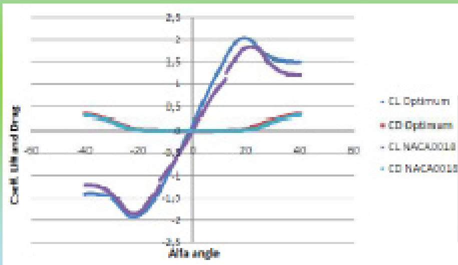
Water current turbine with vertical blade can be used on the river flow, ocean current or tidal current. The three parallel turbines with 40 degree azimuth different has advantages, doubling the power output and diminish the torque fluctuation. When the turbine equipped by the concentrator channeling device, the performance increased and the self starting capability also augmented. During the experiments is indicated the flow phenomenon behind the turbine, the vortex formation created additional head or formation of low hydraulic level and facilitate the turbine coefficient of power produced greater than BETZ limit. The development of water current turbine at Fluid Machinery Laboratory FTMD ITB is starting with searching numerical simulation model at ANSYS 12.1 using NACA0018 blade profile comparing with experiment and carry out that the Reynolds Stress Model is adequate between simulation and the experiments. Further this model simulate variants of *c/R* (Chord Radius Ratio), *TSR* (Tip Speed Ratio), distance of shaft and configuration of the concentrator channeling device at the water flow velocity.

Using NACA0018 blade profile as the best chose from the NACA0012, NACA0015, NACA0021 and NACA0024, Water current turbine equipped by the concentrator channeling device with *c/R*=0,32. The numerical simulation at the flow velocity of 0,4 m/s give *CP* =0,39 at *TSR*=3,2 but at the experiments measurement give *CP* =0,35 and *TSR*= 3,88. Other experimental case at flow velocity 0,6 m/s give *CP*=0,38 at *TSR*=2,18 the experiments and simulation result different is due to the friction loss of the transmission.

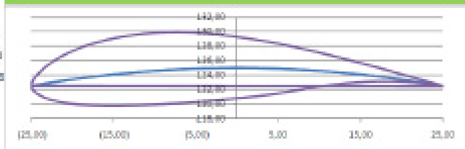
The NACA0018 optimized by using MATLAB and XFOIL has better stall characteristic with angle of attack extend to 45 degree. Equipped by NACA0018 optimized, the three parallel current water turbine with concentrator channeling device numerical simulation at velocity *V*=0,4 m/s produce *CP* =0,64 at *TSR*=3,18 and at Velocity *V*=0,6 m/s produce *CP* =0,51 at *TSR*=2,68.



Airfoil profile of optimized NACA0018



Comparison performance of Opt. NACA



Circular position of blade R=125 mm

Three paralel water current turbine

Experiments results shown has *CP*= 0.64 greater than BETZ limit at the *TSR*= 2.97 on the low flow velocity 0,4 m/s. In the operational is expected its turbine will operated at the higher flow velocity greater than 1.2 m/s to get better power density and the construction will smaller and lighter for unity of power.

This paper demonstrated the parallel VAWT has better performance using the optimized NACA0018 blades and concentrator channeling device give certain benefit to the application. The channeling device mounted at boat could be used as buoyancy control device, and the parallel configuration give the *TSR* higher.

STUDY OF UTILIZATION OF BIOMASS COMBUSTION EXHAUST GAS FOR ORGANIC RANKINE CYCLE POWER PLANT USING COMPUTATIONAL FLUID DYNAMICS

The Waste Incenerator Technology is one of the undeniably processes that has to be applied in Zero Waste System. The High Temperature Gas that occurs from the combustion process can be utilized to generate steam for a Steam Power Plant. This system is called Waste-To-Energy Plant (WTE Plant). The exhausted gas from the Plant still has high temperatures so it can be utilized as a new resource of energy.

Exhaust gas that being utilized for an Organic Rankine Cycle (ORC) Power Plant comes from the exhaust gas from the furnace of a small WTE designed in previous studies. From the results of the study, the temperature of exhaust gas at the outlet of Air Heater is 161.63 Oc and the mass flow rate of gas is 2665.63 kg/hr. This simple ORC system consist of four main components. They are evaporator, turbine, condenser, and pump. Evaporator serves to evaporate organic fluid from liquid to vapor and heated up before entering the turbine. In the turbine the vapor expands release its energy to generate mechanical power and the electrical power when the turbine is connected to an electric generator. Condenser is used to condense the steam that come out from the turbine. Pump serves to increase the pressure of the organic working fluid to the pressure required by the evaporator. Thermodynamic analysis was performed by the Cycle Tempo program. Working fluid used in the thermal analysis are R-245fa and R-134a.

Energy analysis for fluid R-134a using Cycle Tempo

Using the Cycle Tempo Program the operating condition of the ORC cycle can be predicted. The inputs parameters are: evaporator temperature, evaporator pressure, and condenser pressure. The analysis were done for various evaporator pressure and temperature. It can be found that the optimum power output can be obtained if evaporator pressure and temperature is 20 bar and 75°C respectively. At this condition the power output is 2 kW and the thermal efficiency is 22%.

Energy analysis for fluid R-245fa using Cycle Tempo

Similar analysis were done using R-245 fa. It can be found that the optimum power output can be obtained if evaporator perssure and temperature is 20 bar and 125°C respectively and the optimum power output and efficiency is 3.94 kW and 52.8 % respectively.

Radial Turbine simulation with Computational Fluid Dynamics

Turbine used for the designed ORC is a commercial Turbine type IT mini made by Infinity. This turbine is radial turbines and can operate with either is R-134a or R-245fa in accordance with the fluids used in thermal analysis.

Figure 1 shown that pressure of fluid decreases as it flow from inlet to the outlet. This case shows the expansion process and energy is transferred from fluid into the mechanical energy. Pressure difference on both sides of the surface of the turbine will cause the turbine force. Turbine torque generated depends on the size of the force created, while, the force created depends on the difference of pressure difference between the inlet and outlet of the turbine.

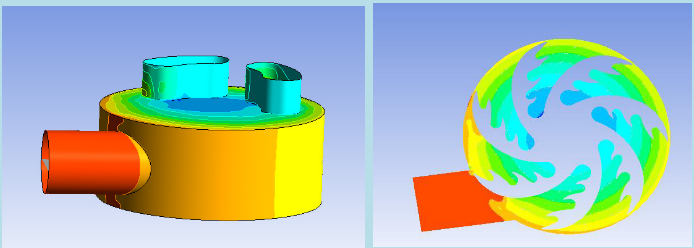


Figure 1: Pressure Contour in rotational speed 12000 rpm

Figure 2 is magnification of the cross-sectional area around the turbine blade. It shows velocity vector comparison. Vortex or rotating flow can be seen clearly in Figure 2 with the indicated line of the rotating arrows located around the turbine blade.

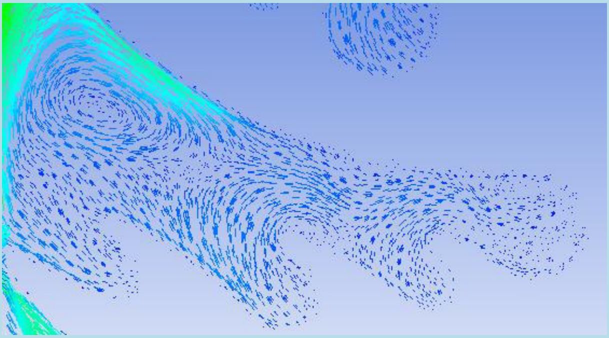
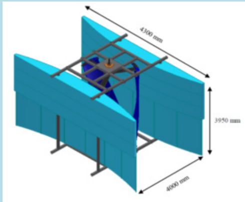


Figure 2: Velocity vector in rotational speed 12000 rpm around the turbine blade

MODEL TEST OF THE WATER CURRENT CATAMARAN TURBINE AND THEIR STABILITY

The aims of this work is to investigate the performance and stability of the water current Catamaran Turbine Prototype. There are three aspects to be considered in designing process hydrostatic, stability, and performance of floating hydroenergy generator to generate power. CFD analysis conducted to investigate the flow around Catamaran and rotating turbine. The flow stream around Catamaran has oscillated moment and force and these could affect the stability.

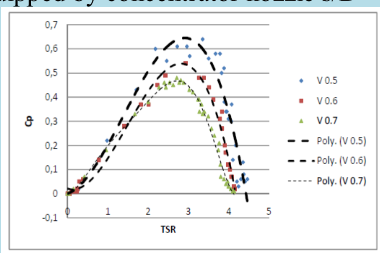
The model of buoyancy device was produced and tested in water flume. The test result shows that buoyancy device has good stability, it may be seen from the ability of the buoyant to keep its position when there is a disturbance on stability.

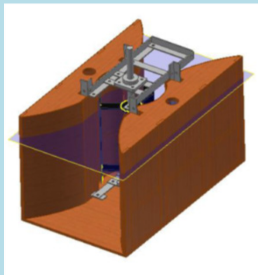


The catamaran buoyancy device

Performance of rotating turbine

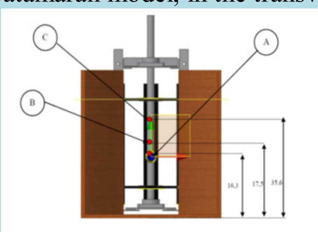
Equipped by concentrator nozzle s/D = 0.8





The initial catamaran model stability

The model submersed in an water is subjected to an upward force equal to the weight of the displaced fluid. The center of buoyancy calculate from the bottom of the Catamaran model, in the transversal direction.



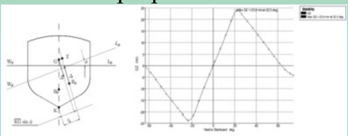
Position of Meta-center (C), Center of Buoyancy (B), Center of Gravity (A)

Center Of Gravity (COG)	163 mm
Center Of Buoyancy(COB)	175 mm
BM Transversal	181 mm
BM Longitudinal	101 mm
Metacenter Transversal (KM)	356 mm
Metacenter Longitudinal (KM)	276 mm
GM Transversal	193 mm
GM Longitudinal	113 mm

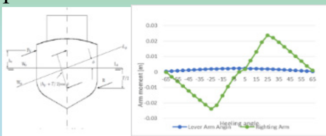
The right arm and the wind heeling arm

The righting arm is the displacement of the center of buoyancy due to the change of line action of the buoyancy force intersection when angle of heel to starboard change.

The stability of the Catamaran model has to be investigates due to the side wind. That is a wind perpendicular to the Center Line plane.



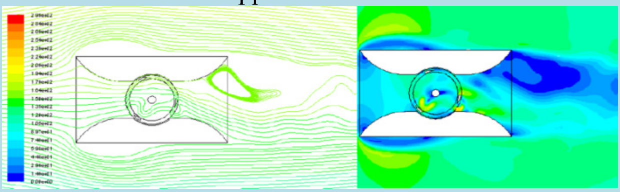
Buoyancy body inclined and the curve of righting arm versus angle of heel



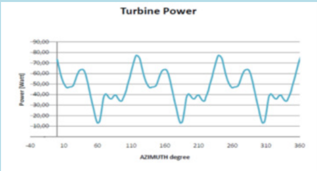
Wind heeling arm and curve of wind level arm

CFD simulation flow around the Turbine Catamaran

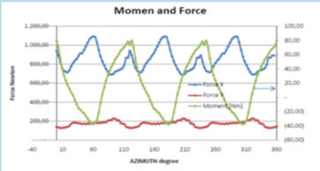
Flow velocity into the concentrator has averaged of 0.9 m/s and accelerated in the concentrator to reach averaged of 1.2 m/s on the turbine interface. The velocity around the Catamaran is 1.5 m/s and the Catamaran has rectangle form, the Vortex Sheeding phenomenon could be happen.



Streamline and velocity contour around Catamaran at 1.5 m/s and 100 rpm



Power of the turbine



Momen and force of the turbine

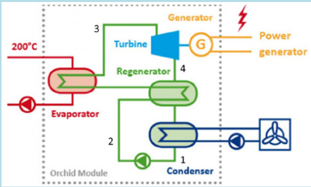
Conclusion

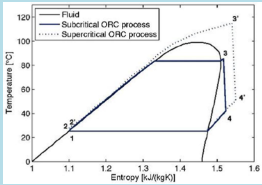
The Catamaran model as a buoyancy device has scale of size 1:8.6 with the prototype. Buoyancy device model draught will increase 6,36 mm with 1 kg weight increased. The statical stability of buoyancy device was characterized by its metacentric height (GM) with longitudinal GM 113 mm and transversal GM 193 mm. The Catamaran has four anchors system to keep stable due to the fluctuated force and moment.

DESIGN OF RADIAL TURBO-EXPANDERS FOR SMALL ORGANIC RANKINE CYCLE SYSTEM

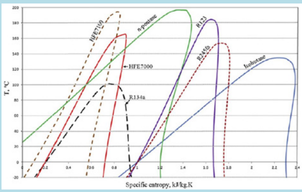
Indonesia consist of many islands, many abundant heat resources such as solar and biomass, refrigeration unit for seafood, agriculture and poultry product in remote area need isolated/out-grid electric power generation, organic rankine cycle could be powered by the solar or biomass heat to produce the electric power.

Organic rankine cycle





Organic fluid



	R134a	R143a	R245fa	n-Pentane	R123
Formula	CH2FCF3	CF3CH3	CF3CH2CHF2	C5H12	CHCl2CF3
Molecular mass	102	84	134	72	153
NBP, ⁰C	-26.3	-47.09	15.3	36.0	27.8
T crit, ⁰C	101.5	72.86	157.5	196.5	183.7
P crit, MPa	4,06	3,76	3,64	3,36	3,66
Latent Heat, at NBP, kJ/kg	155.4	231.0	177.1	349.0	168.4
ODP	0	0	0	0	0.02-0.06
GWP	1300	4300	1030	20	120
Flammability, Toxicity	A1	A2	B1	A3	A1

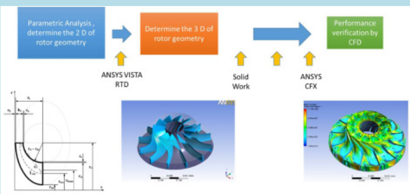
Radial turbo expander

- ✓ Simpler: one piece casting.
- ✓ Compact.
- ✓ Lighter.
- ✓ Large specific power.
- ✓ Higher efficiency

Objective:

- Ouput power 5 – 10 kW.
- Rotor diameter around 250 mm.
- Fluid inlet temperature: less than 200°C.
- Fluid inlet pressure: less than 10 bar.
- Fluid mass flow rate: less than 1 kg/s.
- Rotor speed: 5000 – 30000 rpm.

Methodology

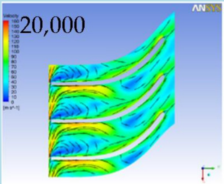


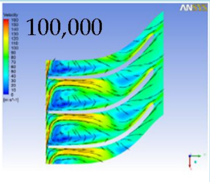
Input Parameter	Unit	R134a	R123	R245fa	R143a	n-Pentane
Mass Flow Rate (ṁ)	kg/s	0.40	0.40	0.40	0.40	0.40
Rotarional Speed (N)	rpm	15000	15000	15000	15000	15000
Inlet Total Temperature (Assumed $T_{01} = T_{04}$)	K	373	373	373	373	373
Total inlet Pressure (assumed $\Delta p_0=0$) $p_{04}=p_{01}-\Delta p_0$	bar	5	5	5	5	5
Loading Coefficient (ψ)	-	0.90	0.90	0.90	0.90	0.90
Flow Coefficient (φ)	-	0.30	0.30	0.30	0.30	0.30
Meridional Speed Ratio (ξ) C_{m4}/C_{m6}	-	1	1	1	1	1
Inlet rotor Radius Ratio (r_{6h}/r_4)	-	0.3	0.3	0.3	0.3	0.3

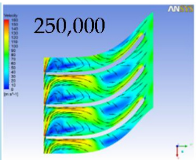
Design results

Result/ output parameter	Unit	R134a	R123	R245fa	R143a	n-Pentane
Absolute meridional velocity (C_{m4})(inlet)	m/s	50	44	43	48	49
Blade speed (U_4)	m/s	167	146	143	160	163
Absolute tangential velocity ($C_{\theta 4}$)	m/s	150	132	129	144	147
Absolute flow angle (inlet) (α_4)	Degree	71.57^0	71.57^0	71.57^0	71.57^0	71.57^0
Relative flow angle (inlet) (β_4)	Degree	-18.43^0	-18.43^0	-18.43^0	-18.43^0	-18.43^0
Absolute velocity (C_4)	m/s	158	139	136	151	155
Relative absolute inlet (W_4)	m/s	52.7	46.38	45.33	50.60	51.60
Inlet Temperature (T_4)	K	360.47	361.15	364.37	362.60	367.37
Inlet Pressure (P_4)	bar	3.60	3.75	3.93	3.85	4.15
Inlet Area (A_4)	m^2	$6.5x10^{-4}$	$4.7x10^{-4}$	$5.3x10^{-4}$	$7.7x10^{-4}$	$8.3x10^{-4}$
Radius rotor (r_4)	m	0.100	0.093	0.091	0.101	0.104
Inlet Blade height (b_4)	m	0.010	0.008	0.009	0.012	0.012
Inlet Density (ρ_4)	Kg/m^3	12.238	19.121	17.384	10.737	9.813
Inlet Mach number (M_4)	-	0.87	0.93	0.85	0.75	0.72

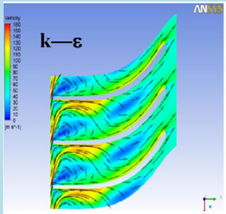
Grid number effect

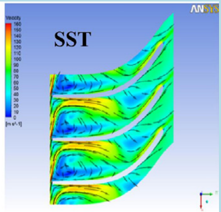






Turbulent model effect





Conclusion

The higher the number of grid will gives better and accurate results. Although time consuming grid number larger than 250,000 is recommended because it will gives different results which shows important phenomena.

DEVELOPMENT OF MONITORING AND CONTROL SYSTEM IN SMART MICRO GRID BASED ON RENEWABLE ENERGY

Indonesia has many remote area and small island which have not get electricity from PLN yet. The most problems are these area far from PLN grid. On the other hand, there are so many potencial energy that can be used for electricity generation in every area such as solar, water and biomass. This research continued the study before about photovoltaic. System smart microgrid is used for this research which consist of 1 kW photovoltaic and 3 kW diesel engine. This research focused on monitoring and control system.

Monitoring and control system conduct in one pack device called Connext Combox (CC) from Schneider Electric. This CC connect with bidirectional inverter and solar charge controller also from Schneider Electric. CC collect and save the data in its internal memory. Data in internal memory automatically save per minutes for one day in one .csv documents. It slightly difference if users save the data using memory card. By using memory card, users can choose the parameters want to be saved. There are 20 data maximum that can be saved in .csv documents such as current, voltage, frequency input diesel engine in bidirectional inverter, current, voltage in battery, load, inverting and charging power, etc.

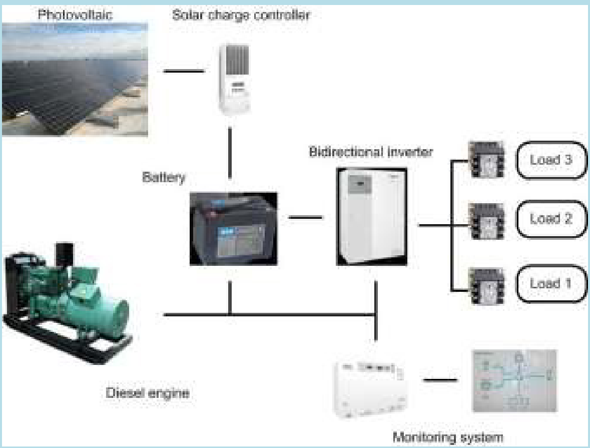


Figure 1. Smart micro grid system

In addition to save data in CC internal memory or memory card, CC also be able to show the real time monitoring system. Figure 2 is the appearance of it. By connecting CC to router then router to laptop, this real time monitoring system can be seen in users monitor.

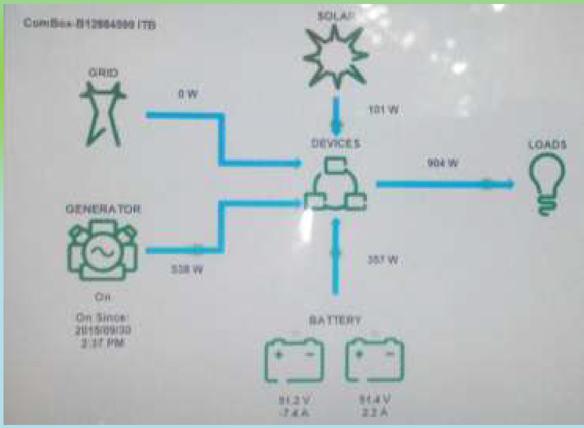


Figure 2. Real time monitoring system

Control system can be done in CC as well. There are some menu to set parameter in bidirectional inverter, solar charge controller, battery, generator and load. Voltage, current, frequency are common parameter which can be set in CC. Noted that before changing the parameters, users should know and uderstand not only the component specification but also the component characteristic. In bidirectional inverter, if the parameter changing out of its range, it will not be changed or users can saved the changing. But, for option such as disable or enable the battery charging, it depend on users requirement. CC can always save the command. Figure 3 shows one of option in CC that can be changed by users.

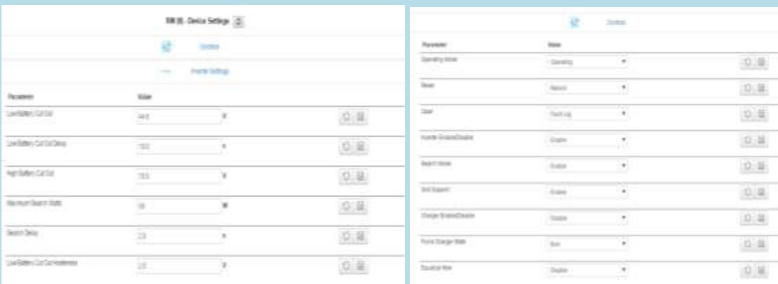


Figure 3. Control system using Connext Combox

DEVELOPMENT AND IMPLEMENTATION OF BIOMASS GASIFICATION BY CHEMICAL ENGINEERING ITB

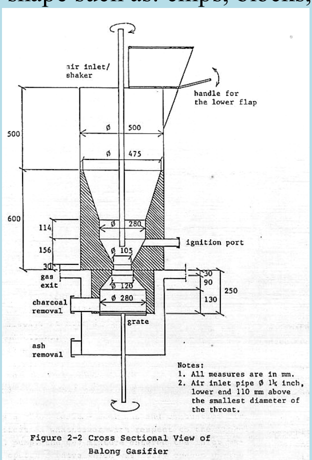
Gasification process is actually an old technology for the conversion of coal and biomass into combustible gases. Research, development and implementation of biomass gasification in our department were initiated in 1977. The aims of our activities were characterization of several types of biomass such as wood wastes, coconut shell, palm nut shell, palm empty fruit bunch, corn cob and rice husk. We extended our activities to evaluate the performance of gasification of those types of biomass and to develop rules of tumb for designing a fixed bed gasifier.

Gasification Process

Gasification may be defined as combustion under an oxygen deficiency and in a good controlled condition. The products of gasification process are combustible gases such as CO and H_2, with some amount of CO_2 and H_2O. Due to the dillution of N_2 from air as the gasifying agent, the gasification product has a low heating value (so called: *producer gas*).

Fixed Bed Gasifier

A fixed bed gasifier (either *downdraft* or *updraft*) is usually chosen for a small scale unit, since it is simple in fabrication and simple in operation (see Figure 1). This type of gasifier requires biomass with particle size in the range of 0.5 – 5 cm and regular shape such as: chips, blocks, and pelletized biomass.



Rules of thumb

for design of *a downdraft gasifier.*

based on our experiences using rubber wood waste with a particle size of $2 \times 2 \times 1$ cm^3:

a. specific capacity, based on area:
   (i) of *throat area* = ±2500 kg/(m^2.h)
   (ii) of *reduction zone* = ±300 kg/(m^2.h)
b. volume of reduction zone per area of throat = 0.5 m^3/m^2 (depends on char reactivity)
c. air flow rate at nozzle = 6 m/s (minimum)
d. air penetration, expected = 17 cm
e. producer gas/biomassa = 2.4 Nm3/kg
f. producer gas/air ratio = 1.5 Nm^3/Nm^3

note: ratio of producer gas/air ≅ 79%/y_{N2};
y_{N2} = mol fraction of N_2 in producer gas

Figure 1. Sketch of a downdraft gasifier with a capacity of about 20 kg/h

Product gas

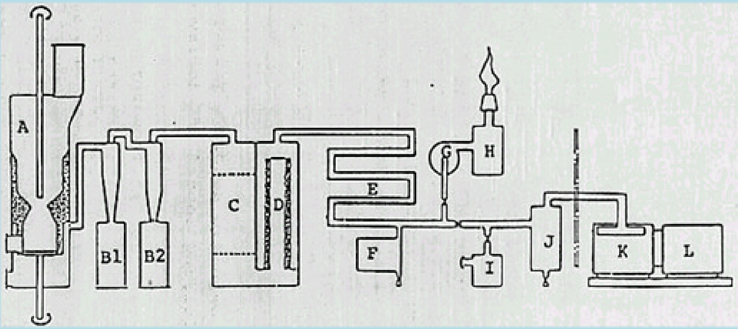
Producer gas (gas produced from gasification of solid with air as gasifying agent) is a *low joule value gaseous fuel* (*low BTU gas*; see Table 1). Producer gas is preferred to be used *in situ* like as a substitute of fuel oil in internal combustion engines or distributed locally with a short distance pipeline for household application.

Table 1. Typical composition of producer gas (our experiments in 1980s)

	type of biomass	coconut shell	rubber wood	rice husk	palm nut shell
1.	shape	irregular chips	regular blocks	loose	irregular chips
2.	particle size, cm^3	2 x1 x 0.5	2 x 2 x4	0.5 x 0.5 x1	1 x 1 x 1
	gas composition and heating value (dry basis)				
3.	CO	25%	18%	20%	21%
4.	H_2	12%	16%	11%	17%
5.	CH_4	1%	2%	2%	2%
6.	CO_2	10%	10%	11%	9%
7.	N_2	52%	54%	56%	52%
8.	heating value, kJ/Nm^3	4.900	4.600	4.350	5.080

Field Experiences

Our first field unit was implemented in in 1984, in a village about 100 km from Semarang, the capitol Central Java (see flow diagram in Figure 2). Rubber wood waste was used as feedstock. This gasification unit was coupled with a diesel engine-generator set to produce electricity of 15 kWe for a settlement of rubber farmers. This unit was operated about 8 hours in the evening and about 3 hours in the early morning. This gasifier was designed based on practical rules available in literature from the past, and our laboratory experiences using a small gasifier (see Figure 1).



A: gasifier
B1 + B2 : cyclones
C: impengement chamber
D: rockwool filter
E : cooler (horizontal pipe)
F : holding tank
G: suction fan for start-up
H: safety tank
I: air filter
J: final-filter
K: diesel engine
L: electric generator

Figure 2. Gasification unit coupled with diesel-generator

In the early 1985, another gasification unit coupled with a diesel genset of 60 kWe was set up for electrification of a small town the border of East Java and Central Java provinces. We got an experience that teak wood waste as fuel underwent thermal fragmentation during pyrolysis process inside the gasifier causing a blockage of the gas flow. After three years in operation, this 60 kWe gasification-genset unit was stopped since the national electricity grid has been available in this small town. While the previous 15 kWe unit lasted after 12 years in operation with minor repair, particularly in parts of the gas cooling and cleaning system, where corrosive condensate accumulated.

In the late of 1985, ten gasification and diesel-genset units based on our design were installed in several locations in Indonesia. In that period, many institutions in Indonesia also dealed with the implementation of biomass gasification for electricity in remote areas. A monitoring program funded by the World Bank was conducted to evaluate the performance of several gasification units in Indonesia, including our 15 kWe field unit. The World Bank monitoring program concluded that the biomass gasification technology with capacities up to 100 kWe were ready to be implemented, with some improvements on gas cleaning and tar disposal systems. The economic feasibility was not yet attractive because the production cost of electricity was still relatively high. Moreover, awareness on the importance of alternative and renewable energy resources was not yet embedded in society and even on the government officers.

In 2008, a gasification unit coupled with a diesel engine-generator with a capacity of 60 kWe was installed in a settlement of oil palm worker, in Pelaihari, a district in South Kalimantan. The unit was fueled with corn cobs obtained from the surrounding corn fields. This unit was stopped in operation when the palm oil mill has been operated in a normal production. This mill generates electricity for palm oil production and office, as well as for staff housing and worker settlements.

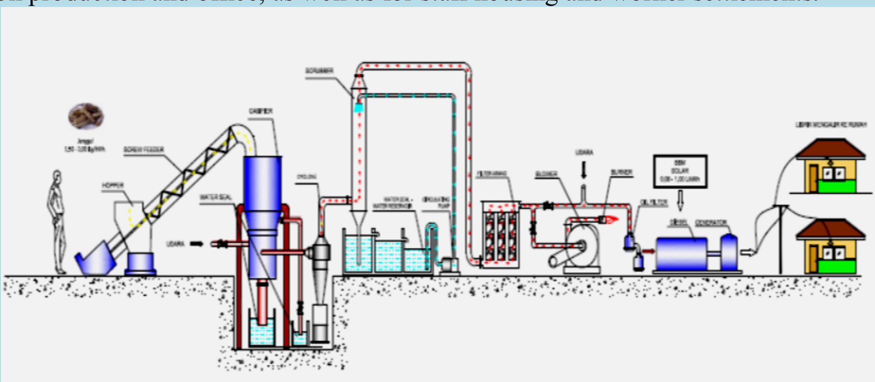


Figure 3. Flow diagram of 60 kWe gasification unit in South Kalimantan

In line with the government policy, five gasification and diesel engine-generator units for rural electricity were installed in Riau Province: two units of 80 kWe and three units of 100 kWe (2010-2011). These units were installed in the worker settlements in the mid of oil palm plantation. They were operated about 8 – 10 h/day (17:00- 24:00, and 04:00-07:00).

Economic Evaluation

Our estimate on the specific invesment cost of a gasification unit was about 580 USD/kW. This figure was more or less similar to those in China for a larger capacity, and was much lower than those in Europe and USA. Of course, the investment cost may vary depending on the quality of process equipments, process guarantee, after sales service, etc.

For estimating produciton cost of electricity, assumptions have been made such as: daily operation of 8 or 24 hour/day and 287 day/year, cost of biomass of 400 or 600 Rp/kg, etc. Surprisingly, the cost of biomass contributed up to 20% of the total production cost of electricity. Contribution of the annualized investment cost of engine-generator and other auxilliaries (with equipments life time of 20 years) were about 20%, and that of maintenance was about 14% (mostly for gasification unit).

We proposed that the investment of the gasification unit should be funded for instance as a grant from the government or a community service from big industries. The total production cost of electricity was about 1500 Rp/kWh. This production cost, without taking investment cost of the gasification unit into account, is very attractive since it was lower than the *feed in tariff* assigned by the government, i.e 1660 Rp/kWh for selling electricity to the national grid in Sumatra island.

Conclusions

Indonesia has gained much experiences in design, fabrication and installation of gasification unit coupled with engine-generator set. Having abundant and various types of biomass, the implementation of the biomass gasification for electricity in remote area should be promoted in Indonesia widely. To increase the economic attractiveness, the goverment should develop a financial policy, particularly for investment of gasification unit.

DESIGN AND PERFORMANCE MEASUREMENT OF THE INTEGRATED LOW SPEED PERMANENT MAGNET GENERATOR WITH THE VERY LOW HEAD TURBINE PROTOTYPE

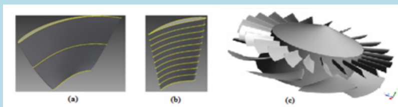
This research is to develop hydropower turbine with low cost of construction and manufacture.The concept is to utilize water flow with a low head to generate electricity and may be used as a small, mini, or micro hydro turbine. The turbine does not require the construction of large dams for water reservoir but the water flow is sufficient enough to drive turbine rotors. This research applied the design of Axial Flow turbine integrated with the permanent magnet generator and the aim of this work is to investigate the performance of the turbine system.

Design prototype

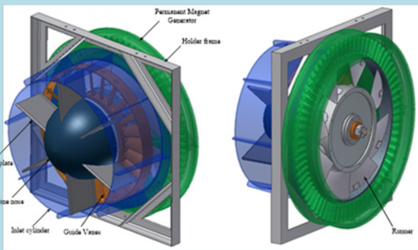
The canal space: 0.84 meters width, 1.15 meters of height and 12 meters long. Flow rate of 128 liter/s and head available 0.3 meters are set as the basic design calculation for the developed turbine. The prototype axial turbine integrated with the permanent magnet generator (PMG) specification :

- The Axial flow turbine will be operated on the rotating speed of 90 rpm.
- Tip and hub turbine diameters are 600 mm and 360 mm respectively.
- The number of blade for stator and rotor are 24 and 8 blades respectively.
- The single phase PMG power output minimum is 300W at 50 Hz.
- Housing diameters of the PMG is 830 mm.
- Turbine position inside the canal is 45 degree from vertical axis.

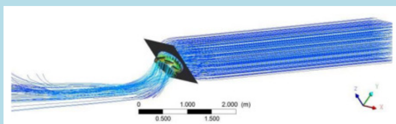
Numerical analyses are conducted to determine the performance of the designed turbine with the commercial CFD.



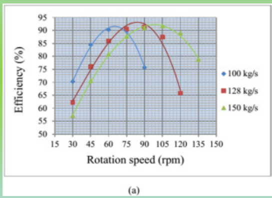
Sample rotor and stator blade development; (a) rotor, (b) stator, (c) rotor and stator blade arrangement.



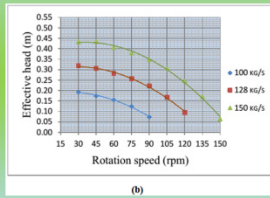
Axial flow Turbine integrated with PMG design assembly.


Turbine installation and fluid flow direction.

Numerical studies result of optimized turbine the maximum efficiency of 91% in the operation conditions of mass flow rate of 128 kg/s, head of 0.22 meters and rotational speed of 90 rpm producing power of 254 Watt.

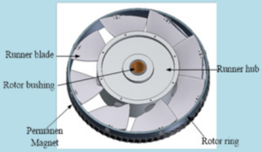


Turbines efficiencies at various rotation speeds and flow rates

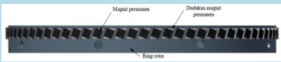


Effective head of turbine at various rotation speeds and flow rate

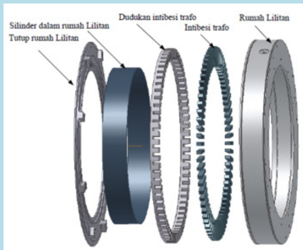
Magnet mounting large angle of inclination is equal to 21.31°. The iron core transformer as stator. Dimension of the iron core transformer is 12.85 mm width, 76.35 mm long and 0.5 mm thick and the number of poles in the design is 72 poles. The result of generator test has power of 329 Watt at 217.9 V and rotational speed of 83 rpm.



Design structure of runner blades with PMG runner



Structure of the PMG with rotor magnet position are tilted



The Stator PMG constuction

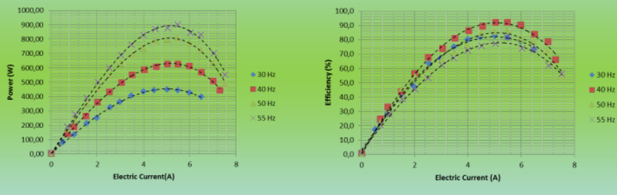
Tabel Materials of main parts of turbine

No.	Main Parts	Materials	No.	Main Parts	Materials
1	Stator of PMG	Silicon steel sheet	9	Rotor hub	Fiberglass
2	Rotor of PMG	Magnet permanent	10	Stator hub	Fiberglass
3	Stator ring of PMG	Mild steel	11	Spindle shaft	VCN
4	Rotor ring of PMG	Mild steel	12	Bushing	Bronze
5	PMG casing	Mild steel	13	Structure cylinder inlet, passage, and shaft base plate	Mild steel
6	Winding	email copper wire			
7	Rotor blade	Fiberglass	14	Structure of stand frame	Mild steel
8	Stator blade	Fiberglass	15	Turbine Nose	Fiberglass

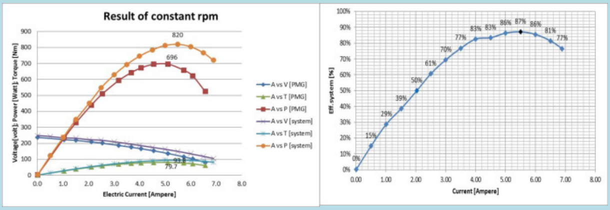
Testing and results

Installation of electrical PMG performance testing

Installation testing of axial turbine with PMG system



Performance test of turbine at fixed frequency



Performance test of turbine at frequency 50 Hz.

Conclusion

- The experimental test of the low head axial hydraulic turbine has succefully demonstrated the good performance of turbine permanent generator system.
- The maximum performance of the turbine with PMG system (VLHHP) is 87% at 50 Hz or equivalent to rotational rotor speed of 83.3 rpm.
- The maximum power generated is 820 Watt, better than the standalone results of the permanent magnet generator which obtains the maximum power generated 696 Watt at the same frequency.
- Design of turbine integrated with the PMG make a major contribution to improving the performance of generator and the overall performance.