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(WS 02) 1000 kW - Study on Ocean Thermal Energy as Electricity Power Generator in West Lombok, Indonesia

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ABSTRACT: In Order to support the equitable economic and science development in Indonesia by fully electrified either in urban or rural area, a revolutionary power generator system which sustainable,renewable and eco-friendly is highly required. WS 02 is an Ocean-Thermal based 1000 kW power generator system which specifically designed to be applied for rural area consist of 500 household such as in West Lombok where the electrification ratio is relatively low. The main components of WS 02 consist of air turbine, power generator, air decompressor and water pump, works by conversing the thermal reaction in particular area of water and turning into mechanical work by using the principle of Open Rankine Cycle then converting it into electrical charge. The system designed to be approximatedly 25 miles off the coastline of the electrified area and 30 years of life-time not only to ensure the efficiency level of the power generated by the generator but also to cut the cost of the energy which consumer to be burdened of. WS 02 enlarge the oppurtunity to decrease fossil-fuel dependency of the people and the government of Indonesia on major aspect of life and create better future.

Keywords: Ocean Thermal, Renewable Energy, Power Generator, Rankine Cycle, WS 02

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1. Introduction

Indonesia is a country under such problem measures as the energy consumption in the country is increasing rapidly at approximated number of 6% every year (2011-2012) where as, the domestic crude oil production has fallen to the number of 6% every year since 2003(Barrientos, Miguel). The price of oil has risen rapidly due to the global-oil-demand-growth which affect on the price of power and increase the rate of inflation which cause many drawbacks on human life. A new kind of energy resource which is renewable energy sources are heavily required to be applicated in all part of Indonesia to sustain the electricity demand and to support the economic expansion. Power deficit or even power crisis will occur if alternative resource does not applied to the power grid system.

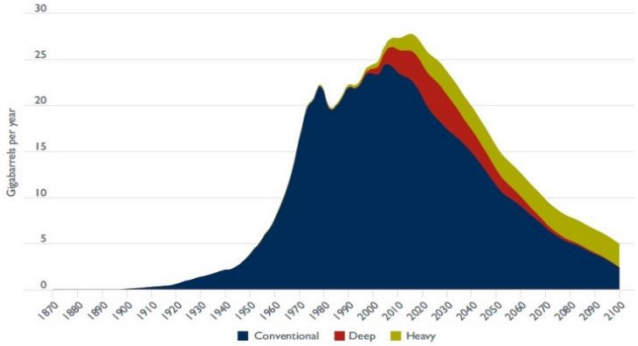

Fig 1.1 World Oil Production. *Source: Dr David Gargett, Energy Bulletin, 22 January 2012*

As the graphic shown above, the global oil production will be at the highest point above 25 Gigabarrel per year in around 2020.

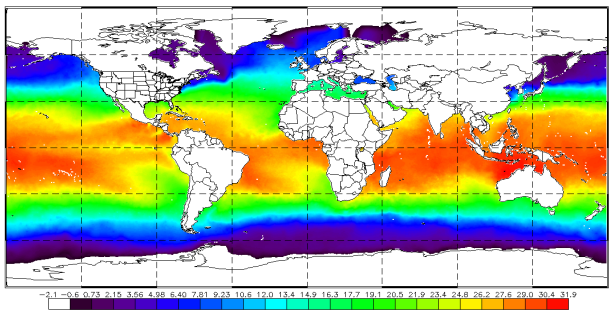

Fig 1.2 Sea SurfaceMean Temperature . *Source: National Oceanic and Atmospheric Administration, monthly Mean SST Chart. 1984-1988*

Indonesia lies on the equatorial line which make the temperature of the climate at high-level-in-relatively-constant as shown Fig 1.2. The Effects of those situation is the blue-print design of the ocean thermal power generator, the pipe length to intake the cold water (deep sea water) into the system is longer which also mean the higher power demand of the water pump as shown on Fig 1.3.

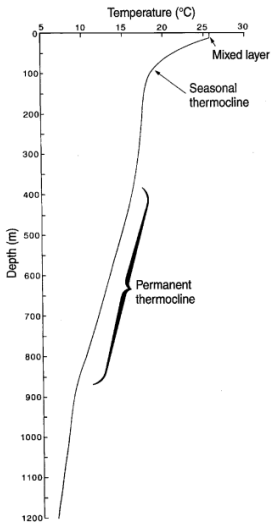

Fig 1.3 Ocean Surface Temperature by Depth, *source: http://scienceofdoom.com/page/19/?themes_on_signup_preview=1*

The sea has the criteria which the temperature significantly decline in the depth of 0 – 100 m so, the depth of the pipe does not require to be very deep and built complicatedly

2. Material and Method

The WS 02 1000 KW-power-generator uses the principle of Open Rankine Cycle by boiling the surface sea water in a chamber by decompress the air pressure inside the chamber using air decompressor, then the steam created by the boiling process get into an air turbine and converted into mechanical force which rotate the turbine. The Rotating turbine then converted into electrical charge by a power generator which then sent to the power grid system of an area. The WS 02 system uses the principle bases of Open-

Rankine-Cycle to reduce the cost of investment and sustain the level of invesment value besides, Close-Rankine-Cycle require Ammonia Freon R-22 and Propane (C_3H_6) as working fluid has a very low point of boiling point at -30°C to 50°C.

2.1 Area of Observation

The place chosen to be the observasion area is about 12 km or 0.75 miles off the lombok coast of Mataram to reach the maximum efficiency point of the system. Not only close to the shore of lombok but the system also placed not to distract any freight and any passanger transportation lane.

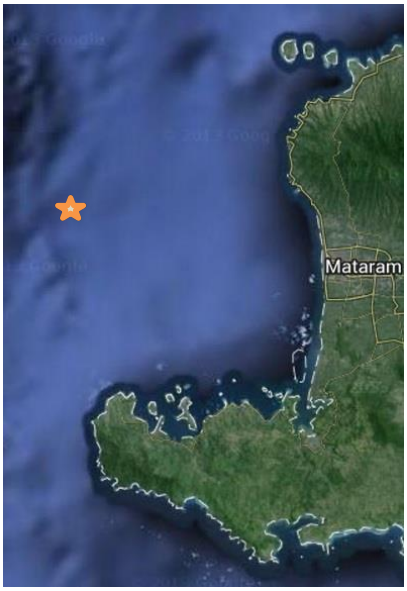

Fig 2.1 *West Lombok Map. Source: Terra Metrics Map Data © 2013 Google*

2.2 Air Turbine and Power Generator

The power generator used in this system is Alternating Current or AC which periodically reverse the direction. The power required to rotate the turbine that generate 1000 KW can be calculated by deviding the power of the generator generates over the difference of work created by the sea water. The radius of the air turbine can also be calculated by deviding the most efficient angle velocity.

$$P = \frac{P_{out}}{\eta}$$

$$\mathbf{P} = \frac{\mathbf{1000\ KW}}{\mathbf{0.85}} = \mathbf{1176\ kW}$$

P = Power (Watt)

The work equilibrium produced by the pump:

$$W_{ps} = v \cdot (P_2 - P_1)$$

$$W_{ps} = 0.001 \cdot (1.088 - 0.101) = 9.88\ kJ\ /\ kg$$

Wps = Net Operating Work (kJ/kg)

Assumed the pump has the rate of efficiency of 65% :

$$W_p = \frac{W_{ps}}{\eta} = \frac{9.88}{0.65} = 15.2\ kJ\ /\ kg$$

Wp = Gross Operating Work (kJ/kg)

η = Efficiency

Fluid Enthalpy before pumping (h_1) :

$$h_1 = h_a + v \cdot (P_2 - P_1)$$

known that:

$v = 0.001$ m^3/kg of water at the temperature of 30°C

P_2 = Fluid Pressure when entering the system = 10.7 atm = 1.088 Mpa

P_1 = 1 atm = 0.1013 Mpa

Then,

$h_1 = 121.65 + 0.001 \cdot (1.088 - 0.101).10^3$

= 122.65 kJ

Fluid enthalpy after water-pumping (h_2 = kJ/kg):

$$h_2 = h_1 + Wp$$

$$h_2 = 122.65 + 15.2 = 137.85\ kJ\ /\ kg$$

In the temperature of 25°C, the enthalpy of the *saturated steam* (H_3) = 2547 KJ/Kg. The heat transfered into the system (Main tank) where evaporation occur is;

$$Q_B = H_3 - H_2$$

$$Q_B = 2547 - 137.85 = 2409.1\ kJ\ /\ kg$$

The gross work produced by the turbine when the fluid reach the temperature of 13°C and at the pressure of 7.6 atm, hf = 55 KJ/Kg and hfg = 2470 KJ/Kg:

$h_{s4} = h_f + (\eta \,.\, h_{fg}) = 55 + (0.9\,.\,2470) = 2278\ kJ\ /\ kg$

$W_{ts} = h_3 - h_{s4}$

$W_{ts} = 2547 - 2278 = 269\ kJ\ /\ kg$

W_{ts} = Gross work by turbine (kJ/Kg)

Assuming the turbine efficiency of 80%,

η = 80% = 0.8

$W_t = 269 \cdot 0{,}8 = 215.2\ kJ\ /\ kg$

W_t = Net Work by turbine (kJ/kg)

The enthalpy when the fluid has reach out the turbine

$h_4 = h_3 - Wt = 2547 - 215.2 = 2331.8\ kJ\ /\ kg$

2.3 Air Turbine

In order to generator 1000 KW disposable power, the amount of steam required to supply the energy is:

$$m_t = \frac{P}{\eta_t (W_* - W_*)} = \frac{1176}{0.95 \cdot (215.2 - 15.2)} = 6.19\ kg\ /\ s$$

The power of the turbine power:

$P_t = \eta_t \cdot W_t \cdot m_t$

P_t = Turbine Power (Watt)

$P_t = 0.95 \cdot 215.2 \cdot 6.19 = 1265\ kW$

2.4 Sea Surface Water Pump (warm water)

In order to determine the power required to intake the surface sea water, finding Heat Energy (Q) is required

$$Q_{in} = Q_B - m_t$$

$$Q_{in} = m_t \cdot (h3 - h2)$$

$$Q_{in} = 6.19 \cdot (2409.1) = 14912\ kJ\ /\ detik$$

$$m_a = \frac{Q_{in}}{c \cdot \Delta t}$$

m_a = Evaporation capacity
Q_{in} = Heat Energy (Warm water into the system)
c = Specific heat of water

$$m_a = \frac{14912}{4.186 \cdot 2{,}5} = 1425\ kg\ /\ s$$

$$P = 9.8 \cdot Q \cdot f \cdot \frac{L}{D} \cdot \frac{v^2}{2.g}$$

Q : Water debit (m^3/s)

f : Friction Coefficient

L : Pipe length (m)

D : Pipe Diameter (m)

V : Water velocity in pipe (m/s)

g : Gravity Acceleration (m^2/s)

$$\mathbf{P = 9.8 \cdot 1425 \cdot 0.05 \cdot \frac{100}{4} \cdot \frac{1^2}{2 \cdot 9.8} = 0.89\ kW}$$

2.5 Deep Sea Water pump

To recondense the steam into liquid form, deep sea water pump used to support the cold water demand.

$$Q_c = h_4 - h_1$$

$$Q_c = 2331.8 - 122.65 = 2209.15\ kJ\ /\ kg$$

$$Q_{out} = Q_c \cdot m_t$$

Q_{out} = Heat Energy (Heat released from the system) (kJ/Kg)

$$Q_{out} = 2209.15 \cdot 6.19 = 13675\ kJ\ /\ kg$$

Finding condensor capacity to condense the steam,

m_b = Condensor Capacity (kg/s)

$$m_b = \frac{Q_{out}}{c \cdot \Delta t}$$

$$m_b = \frac{13675}{4.186 \cdot 2.5} = 1306.7\ kg\ /\ detik$$

$$P = 9.8 \cdot Q \cdot f \cdot \frac{L}{D} \cdot \frac{v^2}{2.g}$$

$$P = 9.8 \cdot 1306 \cdot 0.05 \cdot \frac{580}{4} \cdot \frac{1^2}{2 \cdot 9.8} = 4.734\ kW$$

2.6 Air decompressor

Air decompressor used as the evaporator of the surface sea water in the main tank to reach boiling point and declanation of molecules bonding energy into steam.

$$P_{tot} = 0.89 + 4.734 = 5.624\ kW$$

Assuming that 90% is the efficiency of the air decompressor of the net power output:

$$P_h = 10\% \cdot 1000 = 100\ kW$$

$$P_{st} = 5.624 + 100 = 105.624\ kW$$

$$Pst = Power\ of\ Air\ Decompressor$$

3. Result and Discussion

The WS 02 power generator system which creates net power output of 1,000 KW requires 5.624 kW to power the pump to transfer surface sea water into the main chamber and also to trasnsfer the condesed water from the cycle-process back into the ocean. In the other word, 1,005.624 KW is the total amount of power should be produced by the system to empowered the system itself of 5.624 KW and generate net power output of 1,000 KW. Air decompressor, which decompress the air pressure inside the main chamber, requires 105.624 kW to evaporates the sea water into 6.19 kg of steam on every second. The air turbine is the main motor to generate mechanical force which later to be converted into electric charge by the power generator is sized 2.25 meter in diameter. This System will provide 1000 KW of electricity to empower of estimated 500 household with 2 kW on every house hold in the region and operating time range of 30 years (assuming there would not be any heavy-destructive disaster).

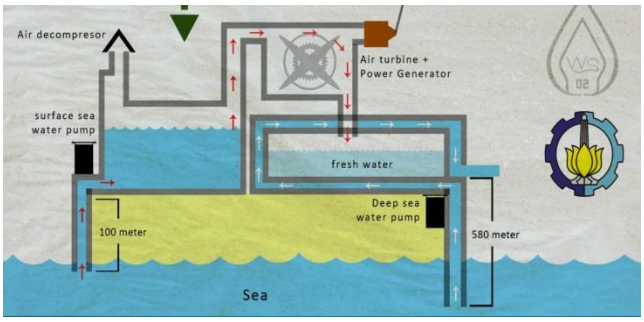

Fig 3.1 **WS 02 Ocean Thermal system**

3.1 Future Development

The condensed steam of the sea water can be used as drinking water to the people or as west lombok irrigation system. Further studies about the fresh water quality and fresh water demand in the region must be held to fulfill the demand of fresh water in the area of west lombok. The future plan of the WS 02 system is to establish multifunction device as sustainable and new sustainable energy source and fresh supplier in to the area of west lombok. Another future development is the mass production of the system to create more economic-friendliness power plant to the people in order of the low rate of GDP per capita in Indonesia .

5. Conclusion

WS 02 1000 KW-Power-Generator is one of the solution to fulfill the requirement of power in Indonesia to form an equitable development all around Indonesia. Ocean Thermal energy is sustainable and widely available to be one of many alternative energy resources to be exploited. In the future using the principal of mass production, ocean thermal based power generator cost can be reduced to meet the equilibrium of the people buying power in all region of Indonesia. The Investments required to make this system to be fully appliable in Indonesia must be generated soon to avoid any power crisis and full support from the center and local govermnet are required to realise this system and create prosperity and development to the people of Indonesia.

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