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Modeling Net Power of Sabah Trough and Its Effectiveness

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Abstract

The prospect of ocean thermal energy conversion (OTEC) system in Malaysia was realized in 2008 by survey carried out in South China sea. Since then various stake holders were sensitize about numerous benefit of renewable energy. The author used the temperature/ depth profile obtained during that survey in 2008 to calculate the net power for Sabah trough using Lockheed Martin proposed model for estimation of OTEC potential worldwide. Their Model developed comprises critical assumptions and account for major contributing and loss factors to electrical power system. The MATLAB was used for the study;the net power obtained was 133.8162MWe.

Keywords: renewable energy, ocean thermal energy conversion, closed cycle system and net power

INTRODUCTION

Unabated interest on renewable energy in developed and developing nations of the world expedite the research on clean energy as a result of global warming and other negative effect non- renewable energy (Nihous 2007). Though economic feasibility has cripple the advance of this energy production in past decadesdue to requirement of huge funds on its construction (Nihous 2008), still companies are moving forward in order to achieve commercial viability of renewable energy systems. In ocean thermal energy system, ocean thermal energy conversion (OTEC) uses temperature gradient between the upper surface and lower surface of the sea with at least 20 degree centigrade (gradient) having depth above 900m or less (Naguary et al 2011). OTEC is a secondary source of solar energy which are found in tropical and subtropical seas with large amount of solar energy leading to increase in surface temperature compare to deep surface water that are much cooler (Coastal Response Research Center 2012).Considering closed cycle ocean thermal energy conversion, A thermodynamic fluid were use (e.g ammonia or freon) in a completely closed system where warm surface sea water(SSW) used to evaporate the liquid and deep sea water condensed the fluid, Thereafter return to the begin of the system Example are 50kw in Hawaii and 100kw by Japanese (Nihous 2005),[US.Department of Energy, 2009), ().Despite the difficulties encounter by many companies involve in renewable energy,they are moving toward the commercial viability of this system. Therefore,Malaysia is among the country that has potential of this renewable energy harnessing it as an alternative source for stabilizing its grid system(Bakar 2009), moreover Malaysia was among 98 Country listed for OTEC development which include fresh water production(Vega 1992).

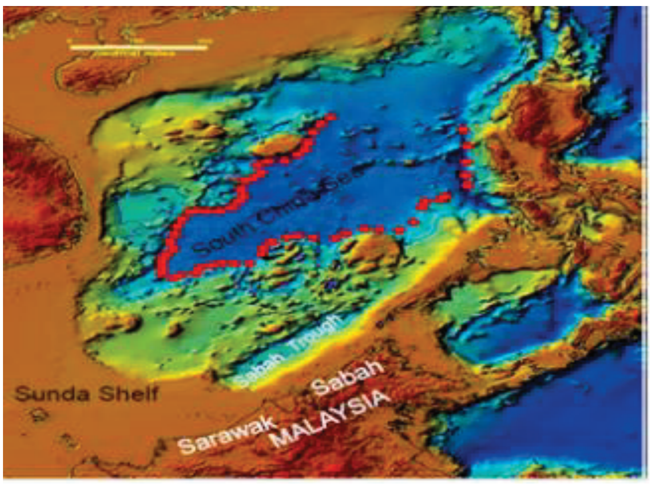

Fig .1 Map showing potential site in Malaysia. (Adapted from UTM-OTEC research centre)

Literature review

History of OTEC System

The first reference author for ocean thermal energy conversion was Jules Verne's, with title "Twenty thousand leagues under sea" in 1870. Follow him on this work is Jacques Arsonoval for closed cycle OTEC. The open cycle was done by Georges Claude 40 years after Arsonoval (Cuba 1930) 22KWe for 11 days. Brazil (1930) Claude construct 2MW as floating plant which give 2000 tons of ice, failure on his part to attempts for installation of long pipe for cold water. Designed of 3MW OTEC by French scientist in Africa 1956, his effort was sabotage due to funding.

The proposed work for open-cycle plant by Bryn Beorse and Professor Everelt D Howe, often founded sea water conversion laboratory at university of California. Also in 1962-73 a research was done by Hilbert Anderson, James H. Anderson, and William E Heronemeus from university of Massachusetts, Clarence Zener from Carneige-Melon University. Their published findings are not pursuing to achieve the intended goal. In 1974-78 the government of Japanese launched sunshine project for research and development of OTEC. The Saga University produced OTEC plant known as Shirasmui 3, of 1KW using Freon 114.

Proposal submitted to US energy research and development Administration (Doe) by Hawaii in partnership with TRW, Westinhouse 1979 felt the open cycle by Claude could be designed using turbine blade technology with cost effective. India 1980-84 studies on OTEC plant rating 1MW (gross) closed Rankine cycle was initiated and prepares by ministry of non- conventional energy resources. Moreover, 1980-89 Saga university for offshore experiment in Japan Tokyo electric co. 120KW IN Nauru and another 50KW OTEC by Kyushu electric co. follow by 75KW experiment in Saga university 1985 Rankine and Kalima generators with working fluid ammonia and water mixture with more advantage.

In Taiwan 1993 a master OTEC plan for the Republic of China reserve power of 30,000 MW. Similarly, similarly Japan 1995 9KW gross power closed cycle lab models at Saga in Japan, follow by designed 1MW gross power OTEC floating plant. In 1997 proposed of 1MW plant by the National Institute of Ocean Technology in India with MOU with Saga University as part of designer. Also in 1998 mooring system for an experimental floating OTEC 1415kg/s of deep cold seawater with 1meter diameter pipeline with depth of 1000m was done. Japan 2007 seawater desalination in OTEC plants was achieved by India NIOT and floating barga called Saga Shakti. Philippines (2009-2010), a United State base company planning investment in Philippines, a unit of California based-deep ocean power is currently conducting studies in 36 sites for ocean power Laong, Zambales, Panay Negoo's part of Mindiano land based power (Henry,2011).

Principle of Operation for Ocean Thermal Energy Conversion

This was based on temperature differences in the surface sea water (SSW) and deep sea water (DSW) with the site having depth of above 900m, the temperature of SSW and DSW of say 31 degree and 6 degree centigrade respectively.

The modes of operation were of two kinds namely; Opened and Closed cycle system. For open cycle thermal energy conversion (OTEC),The sea water was used as thermodynamic fluid where warm seawater was expanded in a chamber which flashes to steam for driving steam turbine at low pressure and the system is cooled using deep sea water (DSW) (Ganesh, 1991) The water from exhaust can serve as drinking water for the community. 210kw were constructed for open cycle (OTEC) in Hawaii as shown in Figure 2.

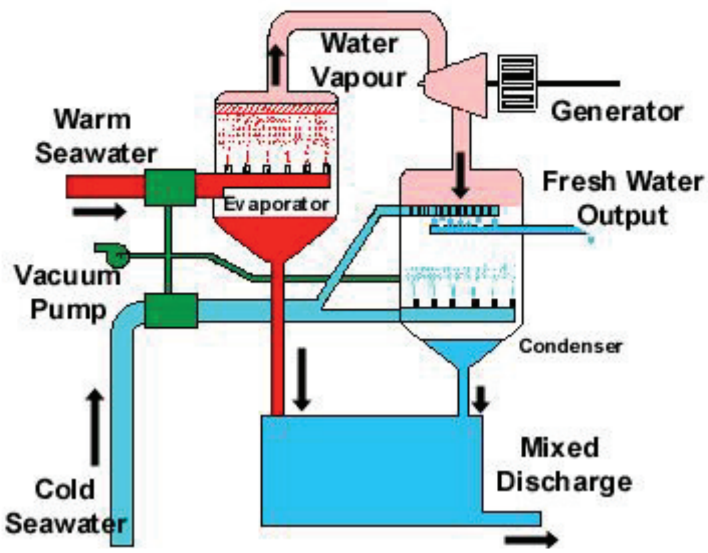

Fig. 2Open cycle system
Source: http://ffden-2.phys.uaf.edu/212_fall2003.web.dir/Yevette_Lancaster/OTEC.htm

Considering closed cycle ocean thermal energy conversion, A thermodynamic fluid were use (e.g ammonia or freon) in a completely closed system where warm surface sea water(SSW) used to evaporate the liquid and deep sea water condensed the fluid, Thereafter return to the begin of the system (Nagurny et al, 2011). .Example is 50kw in Hawaii and 100kw by Japanese.

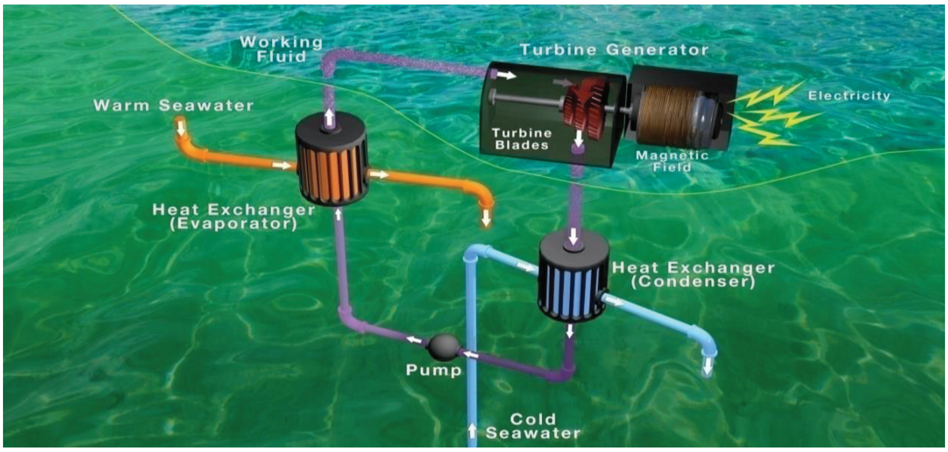

Figure3.Closed cycle system
Source: http://www.gizmag.com/otec-plant-lockheed-martin-reignwood-china/27164/

Description of OTEC model

There are few past researches on estimating OTEC, but recent studies done by (Nihous 2005), and (Nihous 2007) depicted more light on the potential of global available OTEC system. Further studies by Lockheed Martin now allowed local estimation base on technical readiness of OTEC system (MS2, 2012).

The gross power is calculated using established thermodynamic equations of a Rankine cycle

P_{gross}= 106.22$\Delta T^2/(T_s-.25)(\Delta T+273.15)$

T_S and T_d are the surface sea water and deep surface sea water temperature in degree centigrade (Naguary et al 2011).

The net power is calculated by deducting variable loss factor and fixed loss factor from gross power.
According to technical report by (MS2, 2012), these two factors can be calculated:
A. Fixed loss factor; This is calculated as the sum of an intake head loss , losses due to the condenser and distribution piping , warm water pumping and working fluid pumping within the equipment.
1. Cold water intake power loss= pump loss
Factor x Intake head loss
Intake head loss = $CV^2/2g$, where $V=4M/\pi\rho D^2$
Pump loss factor=Mg/Л
But C= Head loss coefficient for protruding pipe entrance
D= cold water pipe internal diameter
ρ= nominal sea water density
Л= sea water pump efficiency
g= acceleration due to gravity
M=cold water mass flow rate
2. Condenser and distribution pumping loss =pump loss factor assumed design head.
3. Evaporator and distribution pumping loss= $M_{warm}gh_{warm}/Л$
M_{warm}= warm water mass flow rate
$_{hwarm}$= warm water head loss
4. Ammonia pumping loss=$Q_{NH3}\Delta P_{NH3}/Л_{NH3}$
Q_{NH3} = ammonia volumetric flow rate=M_{NH3}/ρ_{NH3}
P_{NH3}= ammonia density
B.Variable loss factor; It is depends on the pipe friction and static head loss
1. Pipe friction loss= Head loss due to friction per unit length x pump loss factor
2. Static head loss=($(5.234x10^{-10}d^3-1.378x10^{-6}d^2+1.313x10^{-3}d-.6541)X(-.00599T_S^2+0.031T_S+1025)/(-.00599(T_s-\Delta T)^2+.O31(T_S-T_D)+1025$)-1)Xd
Therefore, Pnet =Pgross -Lvar – Lfixed
Solving the following equations in MATLAB the following results were obtained for Sabah trough:
Gross power = 183.65MW
Cold water intake power loss = 3.7816MW
Condenser and distribution pumping loss = 22.417MW
Evaporation and distribution pumping loss =14.0875MW
Ammonia pumping loss = 2.3732MW
Total fixed loss power factor = 42.6598MW
Total variable loss factor = 7.1740MW
Net power = 133.8162MW

Data used

The data used was adapted from (drmohdkhairiabuhusain), and (MS2, 2012), the values of temperature at 1000m and surface temperature was used in the calculation. Temperature/ depth profile is depicted in the figure below:

Table1.1: Temperature/ depth profile for Sabah trough

Depth (m)	Temperature (^{0}C)
1200	3.50
1000	4.50
800	5.50
600	6.50
400	10.00
200	15.50
0	28.50

Adopted from (drmohdkhairiabuhusain)

Surface sea water temperature (SSW)	28.50^{0}C
Deep sea water temperature (DSW)	4.50^{0}C
Surface sea water flow rate	4.6 x10^{5}kg/sec
Deep sea water flow rate	3.66x 10^{5}kg/sec
Ammonia mass flow rate	4.06x 10^{3}kg/sec
Deep sea water pipe depth	1000m
Efficiency of pump for sea water	80%
Efficiency for generator	97.5%
Efficiency of turbine expander	86%
Efficiency of pump for ammonia	75%

Adopted from (MS2, 2012).

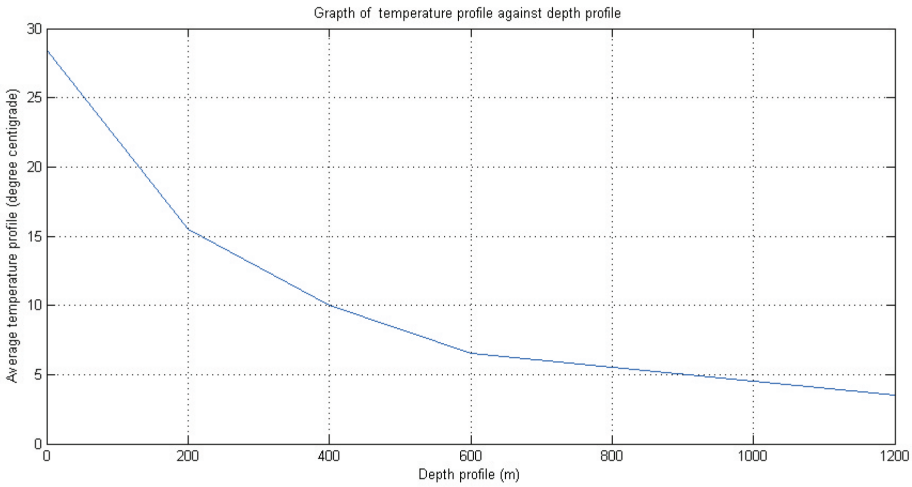

Fig. 4 Temperature profile versus depth profile of Sabah trough

The cost implication of OTEC

According to (Nihous 2008), the economic analysis of ocean thermal energy conversion that is still relevant up till today for all projects in existence was done by (Vega, 1992). This study was reviewed in this research to reflect the economy viability of the OTEC system. Two market systems were considered for the analysis using fuel cost and water production output cost (Reverse osmosis technique to produce fresh water).

1. Industrialized nations and Islands: The fresh water needed by this type of market is 400 litres for each person in one day. 1MWe of electricity will be sufficient for around 2000 people or less while hybrid cycle plant or closed cycle (50MWe) will be able to cater for 100,000 person producing fresh water capacity of 62,000m^3 /day.
2. Smaller or less industrialized Islands: It is a type that 1MWe produce will cater for about 30,000 persons in the island. The larger cycle OTEC can be utilized by 300,000 persons in less developed country having fresh water capacity of 62,000m^3 daily productions. It is worth of mention that the author of this analysis, count the Malaysia among the 98 country that could meet up their electricity and water requirement using OTEC (Vega, 1992).The threshold proposed by (Vega, 1992), for economic viability 50MW/100MW was with water production are 23$/barrel and $20/barrel of oil in the market. But presently the price of crude oil per barrel as at July 2013 was $106(CBN, 2013), are more than four times this threshold, we can concluded that cost of OTEC system in line with fresh water production are effective.

Effect of ocean thermal energy conversion on the environment

If amomonia is contaminated with water with water will have negative effect on marine animals,There should be adequate protection for the habitant of the environment.Also water should be channeled to avoid mixing of hot and cold water which might neutralize the temperature gradient. Appropriate studies should be embarked on the impact of ocean thermal energy conversion on the sorrounding (Hawaii, 2012)

Results

Base on proposed model for 150MW (100MWe) the net power that can be obtained fall between 0 and positive 197MWe (Naguary et al 2011).The result obtained was in conformity with these values. There are few past researches on estimating OTEC, most studies in Malaysia for OTEC system limiting the scope of their finding to 50,000MW of electricity base on gross power. The author deem it necessary to estimate the net power which shows the actual power that can be produce base on available technology as explained in section 2.6. Moreover the potential of global available OTEC system which could still be used for local site vary from one country to the other depending majorly on the temperature profile in respect to depth of the sea. Therefore, this estimate gives room for proper planning for generation, transmission and distribution of viable OTEC system. Base on proposed model for 150MW/100MWe, the net powers that can be obtained fall between 0 and 197MWe. The result obtained was in conformity with these values. Thus the objective 1 was achieved. Employing available technology for OTEC system, the generated power will be in modular form i.e 13 x 10MWe of electricity.

Conclusion

To the best knowledge of the Author, this is the first time net power was obtained based on past work on OTEC in Malaysia and Long term load forecasting was done for net power calculated using weather data of Sabah which is not in the scope of this paper. It is my believe that, adequate framework for OTEC development in Malaysia such as legal-policy ; Territorial Sea Act of 2012 (Exclusive Economic Zone Act, formulation of new law for enhancement of OTEC, an effective plan for a voluntary decrease in emissions intensity of GDP by 40% against 2020 and suggested fiscal policy and private investment initiatives; creation of NKEA (New Key Economic area) for OTEC having budget allocation 120 million US Dollars, UTM OTEC provided with allocation of R&D and commercialization grant of 18 million RM and additional 40 million US Dollars for commercial-demo 4MW OTEC plant off PulauLayang-Layang for more investment attraction by Deep-water oil and gas industry for modular design of 24MW OTEC plant (240 million US Dollars) (Bakar, 2013), will be a platform for achieving function able OTEC system.

Acknowledgement

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