OSMOTIC POWER POTENTIALITY IN THE WORLD

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ABSTRACT
This paper tries to investigate potentiality of Osmotic power. From the base of experiment, it can be said that around 4200-Watt osmotic power could be developed with 3000 litter of brackish water through osmosis principle. From the MATLAB simulation it is observed that osmotic pressure increases sharply with increase of membrane flow.

Keywords: Osmotic, Power, Water, Energy.

1. INTRODUCTION

A good development in the clean energy sector with minimum energy cost can be a good solution for energy crisis as well as for the environment pollution like air pollution, water pollution, climate change etc. (Jacobson et. al. 2011**)** Energy is the only liable part for the control of global economy. The energy consumption is increasing to a great extent globally. Total 60% energy consumption has been recorded as an increment globally from 1999 to 2020 explained by the Energy projects of US department. This is the forecast of 20 years indicating population increment of 1.5 billion (Avinash Mishra 2013)**.** Osmotic Power is considered one of the most important sources as renewable and sustainable. Total 240m hydraulic pressure can be obtained from the osmotic pressure created by the separation of fresh water and sea water. One MW of electricity can be developed from the stream flow of 1 m3/s. Total 2.6 TW power can be collected from the resource of fresh and sea water globally. Salinity gradient for generation of osmotic power, a gradient should be developed between the sea water and river fresh water. Osmotic Power is considered one of the important renewable sources which is totally clean and sustainable creating no environment pollution. To get energy conversion from membrane process of salinity gradient, reverse electro dialysis and pressure retarded osmosis pay a vital role. A study is needed for finding out the performance using these two techniques. This investigation may contribute to the development of these two techniques (Post et. al., 2007).

2. OSMOTIC POWER PRINCIPLE

One of the advantages of algae cultivation in If the fresh water is allowed to mix with salt water of sea, entropy will rise to a good extent for the ionization of salt water. This reaction can deal to the effect of neutralization of the chemical potential deviation. It is estimated that around 2.88 MJ can be developed if one-meter cube of fresh water is allowed to mix with sea water. This huge amount of energy can be used for generation of electric power by the osmotic power plant producing a little temperature in the river mouth. For this technique, it is necessary to make a reservoir of fresh water and a reservoir of saltwater. Between these two reservoirs a semi permeable membrane is placed where a chemical potential gradient is produced and, in this process, the fresh water decreases due to the water addition from fresh water to salt water through the membrane (blocking the salt ion) to neutralize the concentration. In this osmosis process, a good pressure is developed even for a little diffusion of water from low to high concentration commonly presented by $\Delta\pi$ (Zeuner. 2011)

$$\Delta\pi=(c\text{high}-c\text{low})\cdot k\text{B}\cdot T \qquad (1)$$

Here kB= Boltzmann constant, T=absolute temperature, $c$high =high concentration of water and $c$low=low concentration of water.

The flow density, JM is the important parameter for osmotic process which can be stated by equation (2) (Achilli, et. al. 2013).

$$JM=KM\cdot(\Delta\pi-p\text{counter}) \qquad (2)$$

Where KM =permeation coefficient of water for the particular membrane, $\Delta\pi$ = current osmotic pressure (relying on the difference of concentration of the solute), and Pcounter = difference in mechanical pressure. For a closed system, Pcounter = $\Delta\pi$. Pcounter can be reduced by using an outlet in high concentration side. Pcounter can be presented as

$$p\text{counter}:=f\cdot\Delta\pi, \qquad (3)$$

Where f is lying between 0 and 1 which is a dimensionless factor controlled by the turbine flow. f is important parameter in the osmotic process. For membrane flow, SM through a membrane area, AM represents:

$SM = AM \cdot JM = AM \cdot KM \cdot \Delta\pi \cdot (1-f)$ (4)

Figure 1 is representing the Simulink diagram for investigating the osmotic power performance. And figure 2 describes the characteristic of osmotic pressure according to the membrane flow.

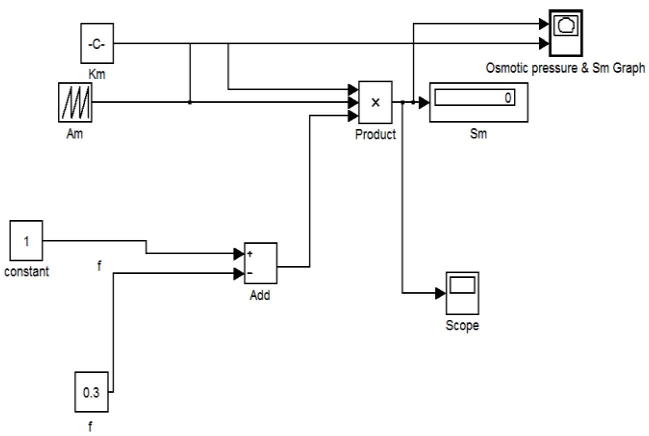

Fig 1: Simulink model of osmotic power & membrane flow

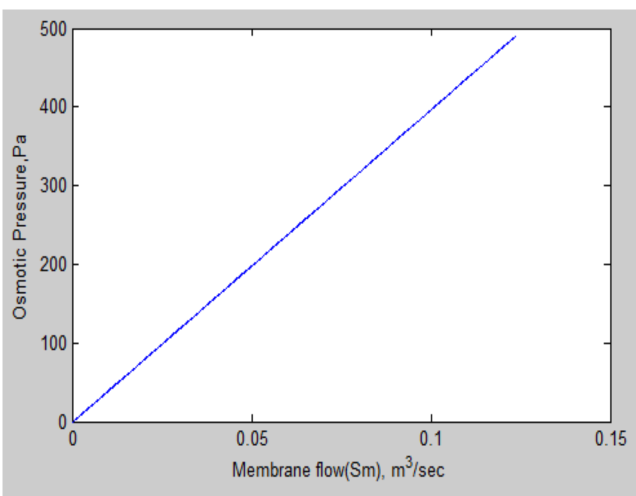

Fig. 2: Osmotic pressure vs. Membrane flow

3. OSMOTIC POWER UTILIGATION TECHNIQUES

- RED- Reverse Electro Dialysis
- PRO- Pressure Retarded Osmosis
- Salinity Gradient Solar Pond

4. PRESSURE RETARDED OSMOSIS

PRO is a typical concept for producing electricity. PRO is working in the process of gradient of salinity created by the separation of salt water and river clean water. In PRO, the water potential of 26 bars is equivalent to a height of (hydraulic head) 270 meters high. However, only 11 to 15 bars can be developed at maximum level. In this process, at low pressure sea water is taken whereas river fresh water is drawn into the chamber via a membrane rising volume as well as pressure of chamber. When the deviation of pressures is created, the turbine starts to rotate. A Norway company named as Statkraft declares that around 25TWh energy can be produced annually using this process in Norway (Avinash Mishra 2013).

5. BLOCK DIAGRAM IN DETAIL

The developed osmotic pressure can rotate the turbine at a good force depending upon the performance of semi permeable membrane. A good salinity levels need to be maintained to increase the performance of pressure exchanger (Melin and Robert 2007).

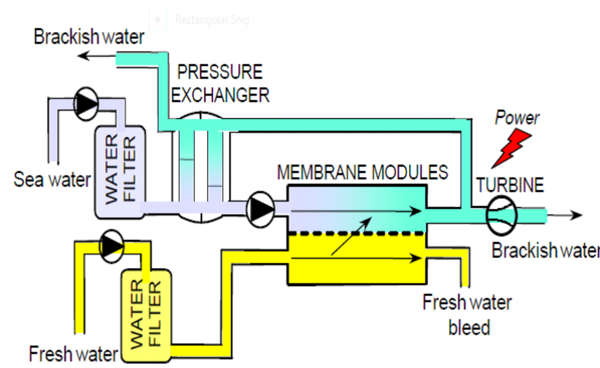

Fig.3: Operation of Osmotic Power

From figure 3, it is seen that fresh river water and salt water of sea are being taken into two separate modules where a semi permeable membrane is placed between the contact of salt and river water. This membrane allows the river water to pass to the salt water making a high pressure in the sea water module. This generated high pressure can rotate the turbine to a good speed producing electricity (Melin and Robert 2007).

For experimental set up, height of water is measured to calculate the potential energy. In this experiment volume of water is changed with fixed pressure. Whereas the volume is fixed but pressure is changed according to the model of figure 3. An appropriate assumption can be made by Boyel's law.

Before Experiment:

Fresh Water Volume = 1000 cc

Salt = 20 cc

Salt Water Volume = 250+20=270 cc

Salt Water for experiment= 86 ml or cc and

Mass =85 gm.

Fig. 4: Before Experiment

Table 1: Experimental data

Time	Height
5:12 PM (START)	5.55 cm
5:23 PM	5.56 cm
5:32 PM	5.88 cm
5:42 PM	6.10 cm
5:52 PM	6.40 cm
6:02 PM	6.40 cm
6:12 PM	6.40 cm

After Experiment:

Salt Water Volue = 95 ml or cc and mass = 94 gm
In case of potato membrane
P = m/v
= 85g/86cc = 0.98837 g/cc
Where
p = salt water density
m = mass
v= volume
Starting time:

Potential Energy = mgh
= 85g×(9.8ms-2)×0.055m = 0.045815 J

At Last: Potential Energy = mgh
= 94g×(9.8ms-2)×0.064m = 0.0589568 J

Difference in 40 min: (0.0589568 J-0.045815 J) =0.0131418 J

Power = Energy/Time
= 0.0131418J/(40×60)s = 5.47575×10^{-5} Watt

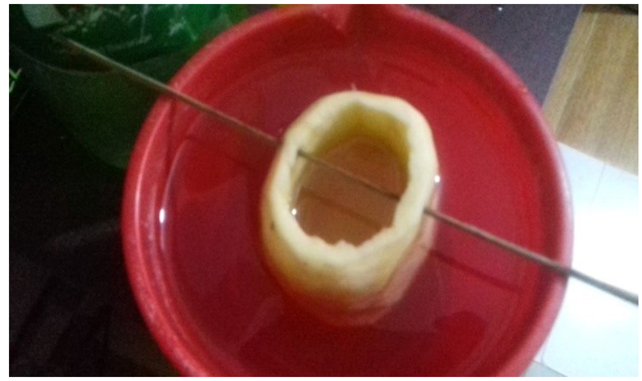

Fig. 5: After Experiment

5. OPTIMUM POWER PLANT EFFICIE

In the first approximation, the power plant consists of the pressure exchanger and the power generating turbine with a pump which needs electric energy. All other technical energy glosses are not considered in this paper.

Power output is

$$P_{PP}=f\cdot k_B\cdot T\cdot[\eta_T\cdot S_M-(\eta_T\cdot\rho_V+\epsilon_{PX})\cdot S_B] \quad (5)$$

The extracted electric energy *EPP* per volume of freshwater results in

$$E_{PP}==f\cdot 1.55\ \text{MJ/m}^3 \quad (6)$$

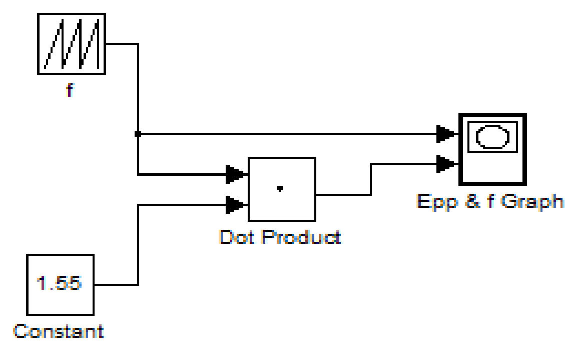

Fig 6: Simulink model of Epp vs f graph

Fig. 7 shows that extracted energy increases with the increment of ratio of operating pressure and osmotic pressure. Maximum extracted energy obtained at the maximum value of f.

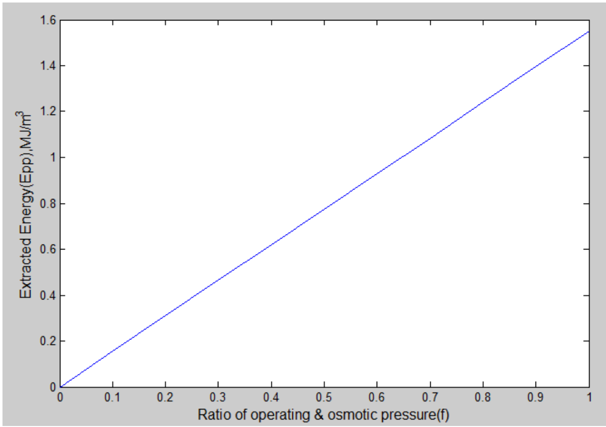

Fig. 7: Extracted energy vs. ratio of operating and osmotic pressure

The maximum profit can be calculated by

$$f_{max}=1-\sqrt{\frac{CM}{CE.\tau.Epp.KM.\Delta\pi}} \quad (7)$$

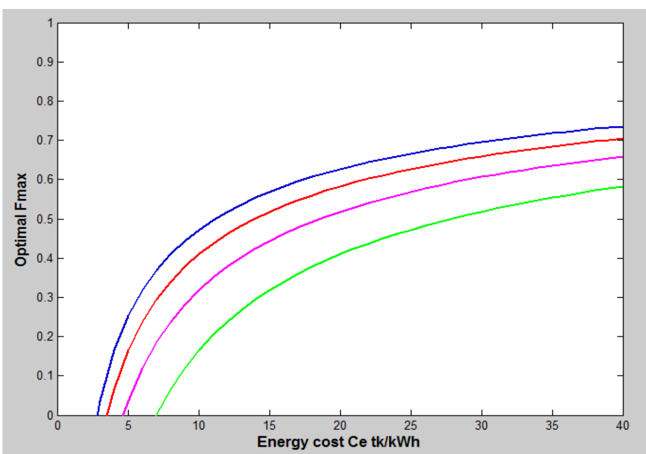

Fig. 8: Optimal F_{max} vs. Energy cost

Here

---------K_M=2---------K_M=4

---------K_M=3---------K_M=5

From the figure 8, it is observed that f_{max} is more economical for the lower value of K_M.

If the ratio of operating pressure and osmotic pressure is maximum then it is possible to minimize the energy cost.

The efficiency of this Osmotic power is 91.0%.

$$\eta_{PX} = \frac{E_{mech\ Salt}}{E_{mech\ brackish}} \quad (8)$$

The Efficiency(ηpx) of the Osmotic power is given by the above expression.

$E_{mech,salt}$ is standing for the energy potential of salt water. $E_{mech,brackish}$ is standing for the energy potential of fresh water.

6. OVERALL RESULT

Here we consider efficiency is 90% for hydroelectric power generation.

Table 2: Tentative result of Osmosis process.

Salt water volume, L	Osmotic power, Watt	Mechanical energy per year, kWh	Electrical energy per year, kWh
86ml or 0.086 L	5.47575 $\times 10^{-5}$ Watt	4.796757 $\times 10^{-4}$ kWh	4.3170813 $\times 10^{-4}$ kWh
500 L	116.63899	1021.757552	919.581797
1000 L	466.55589	4087.029596	3678.326637
1500 L	1049.75057	9195.814993	8276.233494
2000 L	1866.22324	16348.11558	14713.30402
2500 L	2915.97381	25543.93054	22989.53748
3000 L	4199.00228	36783.25997	33104.93398

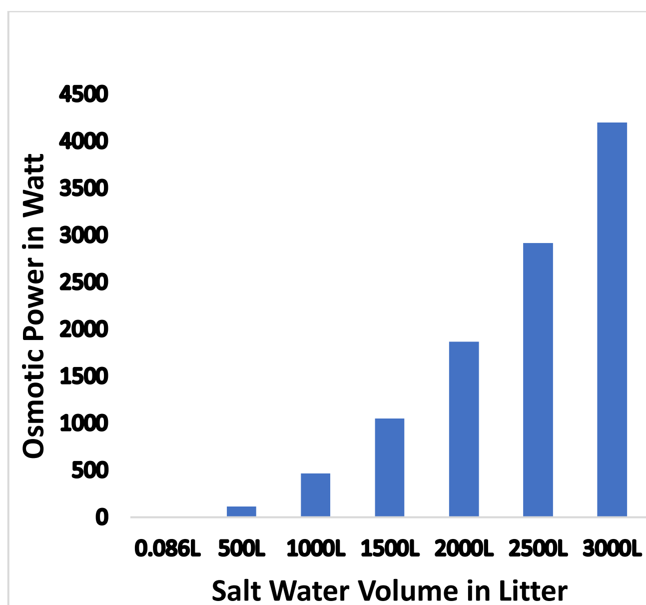

Fig. 9: Osmotic Power vs. Salt water volume

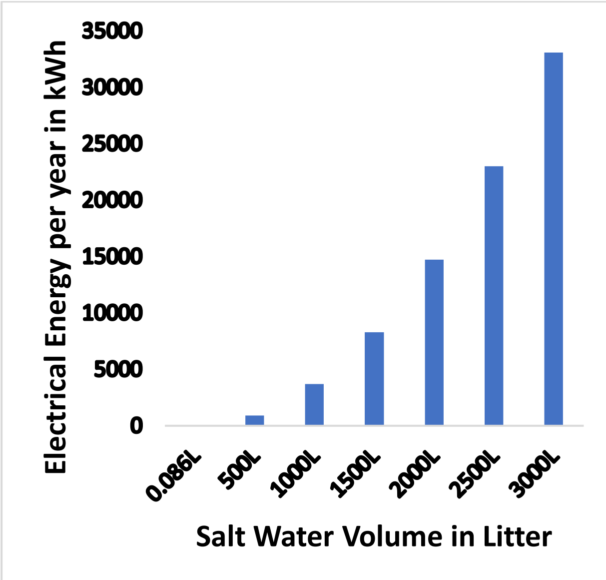

Fig. 10: Electrical Energy vs. Salt water volume

Both figure 9 and figure 10 represent that osmotic power could be developed to a very significant level if the larger volume of water can be operated for osmosis process.

7. CONCLUSION

Around 2000 KWh electrical energy per year could be developed if the salt water volume is increased by 500 litters through osmosis process. From the MATLAB simulation it has been observed that for the maximum value of f (ratio of osmotic pressure and operating pressure) energy cost is low. To make osmotic power generation in a commercial manner, more research works are needed. However through the development of the membrane technology and implementation of osmotic power plant, osmotic energy may take the place of alternative for the fossil fuel.

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