Design And Development of Osmotic Power Generation Model

Aniket. E. Shewale[1], Pratik. M. Shirude[2], Sagar. N. Shinde[3], Shrikant. H. Salunkhe[4], Prof.Sandhya D. Jadhav[5]
[1, 2, 3, 4] Dept of Mechanical Engineering
[5]Professor, Dept of Mechanical Engineering
[1, 2, 3, 4, 5] BharatiVidyapeeth College of Engineering, Navi Mumbai, Maharashtra – India

Abstract- *Consumption of energy is an important aspect in our day to day life. Energy consumption rate is increasing as the population and industrial sector are growing rapidly. Due to increase inthe energy consumption the world is facing shortage of energy supplies. So to full fill the necessary energy more sources of energy rather than the non-renewable sources of energy are to be studied and researched. There are many forms of renewable energy sources in the world like solar energy, tidal energy, wind energy, Geo thermal energy etc. The osmotic power is one of the latest processes to produce the energy.The power from osmosis or osmotic power or salinity gradient power is the energy available from the difference in the salt concentrations between seawater (saline water) and river water (fresh water). Salinity gradient power is a specific renewable energy alternative that generates renewable and sustainable power by using naturally occurring processes. The process for power generation was examined and also design of required components is carried out.*

Keywords- Energy, Osmotic power, salinity gradient, Renewable.

I. INTRODUCTION

The global energies supply for human activities are dominated by fossil fuel combustion and consumption. In India, 75% of the energy is supplied by this source, contributing significantly to global climate change. To exacerbate this issue, growing economy and population are projected to lead to increasing demands for energy in India. Non-renewable energy resources consumption mainly constitutes coal (60%), gas(8%), and nuclear power (2%).

It is estimated that only 30% of our energy is sourced by renewable resources, mainly wind power (9%), solar power (3%), hydro (13%), bio power (2.4%) and rest (2.6%).Total primary energy consumption is projected to grow by approximately 11% by 2040 according to International Energy Agency(I.E.A).

For the reduction of dependence on fossil fuels to satisfy the growing energy requirements, new alternatives have to be explored, particularly renewable sources due to the least impact on our environment.

A new type of renewable and pollution free energy which came into limelight is salinity-gradient energy (osmotic power). It is based on the liberation of energy upon mixing of

waters with different salt concentrations, as between rivers and oceans. When properly constrained, this energy can be used to generate power. Recently, osmotic energy has been introduced as a source of renewable and sustainable energy, whereas it shows potential for power generation.

Salinity gradient energy (SGE), which utilizes the chemical potential difference between two solutions having different salinities, has recently gained attention as a promising candidate to reduce the dependence on the fossil fuels. Approximately 0.63 kWh of free energy can be harvested by mixing 1 m3 of fresh water and seawater. In addition, the potential of SGE is estimated to be ~2.6 TW, which might make it possible to cover the global energy consumption demands. Other factors that make this technology more favorable include the fact that no emissions of greenhouse gases such as carbon dioxide are produced and there is less dependence on the weather and seasonal conditions compared to renewable energy technologies such as solar and wind energy.

II. WHAT AND WHY IS OSMOTIC POWER?

The energy obtained from the difference in potential salinity difference between seawater and fresh water, converted into electricity with the help of a hydro-turbine.

The thing is that the osmosis process is not directly used to generate power. The main purpose of this process is that to create a flow through the plant and created flow, forces the turbine to rotate and thus power is produced.

Osmotic Power is the highest energy concentration source (i.e. energy density, refer Table I) of all marine renewable energy resources, knowingly an ultra-dense energy resource.

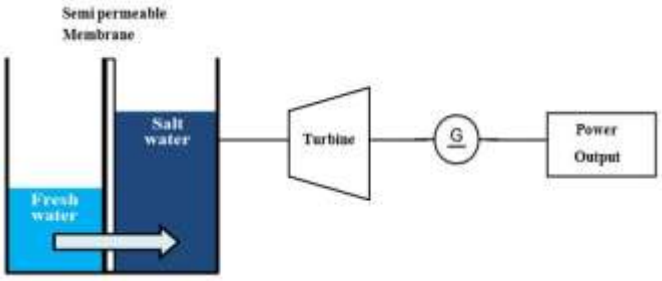
There is no fuel cost in this power generation. Salinity Gradient osmotic power produces neither Carbon Dioxide emissions nor other significant effluents that may harm or interfere global environment.

In Norway the trend is more popular which not only supplies the country's power demands from the hydroelectric plants; it is also exporting electricity to the neighboring countries. Recently, Norway has started a new power plant called the Statkraft Power Plant that utilizes osmotic pressure to generate electricity that is power generation. The TABLE I shows Resources with energy density

TABLE I Resources with energy density

Resources	Energy Density (J/m3)
Ocean waves	1.5
Salinity gradient	240
Thermal gradient	210
Tides	10

III. WORKING



Block diagram of osmotic power generation

The Fig. 1 illustrates block diagram of Osmotic Power Generation. Here in this process, water with no or low salt concentration is fed into the plant and also filtered before entering the membrane modules using the pre-treatment equipments. Membrane modules could contain spiral wound or hollow fiber membranes. In the module, 80–90% of the water with low salt gradient is transferred by osmosis across the membrane into the salty water. The osmotic process increases the volumetric flow rate of high pressure water and is the main energy transfer in the power generation process. All This requires membranes with particularly high water flux and excellent salt retention properties. After this process the brackish water is fed to hydro turbine. Due to this turbine rotates and mechanical power is produced and shaft attached to the generator also rotates and thus power is generated.

The illustration in figure shows salty water pumped from the sea and filtered before fed into the membrane module. In the module it is diluted by the water received from the less salt concentrated side of the membrane. The volumetric feed of salty water is about twice that of the fresh water.Higher the salinity gradient between the fresh and saltwater or sea water, the more pressure will be developed in the system. Similarly, when water with high flow rate enters the system, the more power can be produced. At the same time, it is important that the fresh water and sea water is as clean as possible. Fouling is the phenomenon in which the substances in the water may get captured within the membranes support structure or on the membrane surfaces, which will reduce the flow through the membrane and hence reduction in power output. This is linked to the design of the system, to the characteristics of the membrane, and to the membrane element.

IV. DIFFERENT TYPES OF OSMOSIS

A. Forward Osmosis (FO)

Forward osmosis (FO) is an osmotic process that uses a semi-permeable membrane to effect separation of water from dissolved solutes. The driven force for this separation is osmotic pressure due to salinity gradient,such that drawing solution of high concentration (relative to that of the feed solution), is used to induce a total flow of water through the membrane into the draw solution, thus effectively and efficiently separating the feed water from its solutes. This process is naturally occurring process. Also it is time consuming. Thus for reduction in time consumption the other methods or types are used.

B. Pressure Retarded Osmosis (PRO)

PRO is somewhat based on the concept of forward osmosis between two liquids with different concentration, which are placed besides, separated by a semi permeable membrane only. The semi permeable membrane allows solvent molecules, which are generally smaller in diameter, to move across it but retards diffusion of solute molecules. Such movement does not consume any energy. In a generalized model of PRO electric generator, solvent used is water and solute is mainly sodium chloride or salt. Hence intense osmotic pressure is created in it. This pressure, calculated based on the concentration gradient of fresh water and sea water, can go up to 20 bars, which is roughly equivalent to potential energy of a column of water stored 230 meters above ground level. The pressure created thus canbeused to turn the turbine to generate power. Currently, PRO is trending and new concept in renewable power generation technology and may come in focus.

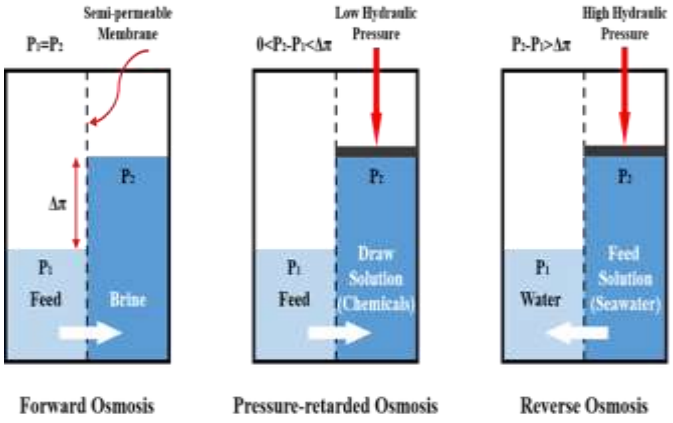
C. Reverse Osmosis (RO)

Reverse Osmosis is a process in which a solvent passes through a porous (minute holed) membrane in the opposite direction of natural osmosis when subjected to a hydrostatic pressure greater than the osmotic pressure.

D. Reversed Electro Dialysis (RED)

Reverse electro dialysis (RED) is the salinity gradient energy derived from the difference in the salt concentration between seawater and river water.

The Fig.2 explains Processes of Osmosis



Processes of Osmosis

V. COMPONENTS DESCRIPTION

A. Water Tank

Water tank is used for storage of fresh water and salt water.

B. Semi permeable Membrane

Semi permeable membrane is essential component for osmosis process. Types of semipermeable membrane which can be used in osmosis process are as follows:

i) Cellulose acetate membrane

The cellulose acetate membrane is prepared as following: The casting solution is cast on a glass plate and immersed or dipped in ice cold water after solvent evaporation. When the mixture is solidified after that the membrane is annealed between 80° and 95°C. A conventional or typical casting solution, according to a GKSS patent, consists out of cellulose triacetate, dioxane,cellulose diacetate, acetone, acetic acid and methanol. The made composition was kept, but because of change in the casting parameters, in the lab and in pilot scale both, the performance of it was improved. The parameters of casting like speed of casting, temperature changes in coagulation bath and also the changes of the support material led to the improvement in the performance. Beginning with a membrane performance of approximately 0.5 W/m2, such membrane was improved to a performance of close to 1.3 W/m2.

(ii) Thin-film composite (TFC) membrane

TFC membranes are made by the interfacial polymerization of trimesoylchloride and m-phenylenediamine. Starting with a membrane performance of approximately 0.1 W/m2, this type of membrane was improved to a performance of close to 3.5 W/m2.Thin-film composite membranes are comparatively more efficient than cellulose acetate membranes.

C. Hydro Turbine

Hydro Turbine is used to convert potential energy and kinetic energy of water into mechanical work

D. DC generator

DC generator is used to convert mechanical power developed by turbine into electricity.

VI. EXPERIMENTAL WORK

A. Design of turbine (Pelton)

Theoretical Power Developed:

$P = \eta \rho g Q H = 0.9 \times 1004 \times 9.81 \times 0.3 \times 10^{-3} \times 1.2 = 3.2$ W

Jet Velocity

$V_j = C_v \sqrt{2gH} = 0.98 \sqrt{2 \times 9.81 \times 1.2} = 4.75$ m/s

Speed of turbine

The TABLE II shows D_{wheel}/d_j ratio and corresponding turbine efficiency

TABLE II D_{wheel}/d_j ratio and corresponding turbine efficiency

D_{wheel}/d_j	6.5	7.5	10	15
N_s	35	32	24	15
η	0.82	0.86	0.89	0.895

$N_s = 15$

$N = \frac{N_s \sqrt[4]{H^5}}{\sqrt{P} \times 10^{-3}} = 15 \frac{\sqrt[4]{1.2^5}}{\sqrt{3} \times 10^{-3}} = 300$ rpm

$\frac{D_{wheel}}{d_j} = 15$

Peripheral Speed of turbine:

$U = \frac{\pi D_{wheel} N}{60} = \frac{\pi \times 0.15 \times 300}{60} = 2.356$ m/s

Runner wheel Dimensions:

$d_j = \sqrt{\frac{4Q}{\pi C_v \sqrt{2gH}}} = \sqrt{\frac{4 \times 0.3 \times 10^{-3}}{\pi \times 0.98 \sqrt{2 \times 9.81 \times 1}}} = 0.01$m

d = 0.01 m

$D_{wheel} = 0.15$ m

Bucket (Vanes)Dimensions:

Width of Bucket = B = 3d = 3× 1 = 0.03 m
Height of Bucket = L = 3d = 0.03 m
No of Buckets = 15

VII. DESIGN SPECIFICATIONS

The TABLE III describes Component Specifications.

TABLE III Component Specifications

Sr.no	Item	Specification
1	Pelton hydro Turbine	Diameter of wheel = 0.15 m Height of vane = 0.03 m Diameter of shaft = 0.03 m
2	Water Tank	Length = 0.6 m Breadth = 0.4 m Height = 0.6 m Partitioned equally into three parts along length
3	DC Generator	Voltage 12 V Material – Aluminum, Copper
5	Rechargeable Battery	12 V
6	Semi permeable Membrane	Cellulose acetate membrane (Flat sheet)

VIII. RESULTS

Theoretical power developed for 0.6 m = 1.6 Watts
Experimental Power developed for 0.6 m = 1.12 Watts
Theoretical power developed for 1.2 m = 3.2 Watts
Experimental Power developed for 1.2 m = 2.73 Watts

IX. OSMOTIC POWER PLANT OPTIONS IN INDIA

The TABLE IV shows major rivers falling into sea so that there is difference in salt concentrations and hence osmotic pressure is generated.

TABLE IV Major rivers falling into sea

Rivers	Delivers to	Location
Narmada	Arabian sea	Gujarat
Tapi	Arabian sea	Gujarat
Mahanadi	Bay of Bengal	Orissa
Godavari	Bay of Bengal	Andhra Pradesh
Krishna	Bay of Bengal	Andhra Pradesh
Kaveri	Bay of Bengal	Tamil Nadu

The Fig. 3 illustrates Indian Coastal Belt showing several rivers falling into sea

Indian Coastal Belt showing several rivers falling into sea

X. ADVANTAGES

- Power produced has minimum environmental impact.
- Renewable energy resource.
- Pollution free process.
- Heat obtained is not harmful for the marine organisms.
- Full year power generation
- Less expensive than regular hydro power plant

XI. DISADVANTAGES

- The chamber or casing must be mechanically very tough.
- Osmotic Power plant is very expensive than fossil fuel based systems.
- Fouling of membranes
- Scaling of turbine blades

XII. CONCLUSION

- Power generation using osmosisis examined in this paper. World's energy consumption is increasing day by day. Also fossil fuels are depleting rapidly. So to overcome this problem it is necessary to search new sustainable energy source. Osmotic energy is a good option to fossil fuels and current techniques.
- While experimenting, there are membranes related issues such as fouling of it, being very expensive and also arrangements of it. As the brackish water is sent to the turbine for generation of power, due to salt content in the mixture there is scaling on turbine blades. But this can be overcome by coating the blades (vanes) by using gun metal. Half yearly maintenance of the components or of the plant is necessary and thus makes very expensive.
- Currently this method of electricity generation is not quite feasible, but in the near future this can be an alternative. More research regarding improvement of this process is required to make the overall process more efficient and cheaper than other alternatives.

XIII. NOMENCLATURE

TABLE V Terms used with units

Symbol	Description	Unit
□	Density of brackish water	Kg/m3
g	Acceleration due to gravity	m/s2
Q	Discharge to turbine	m3/s
H	Net Head	m
V_j	Jet velocity	m/s
U	Peripheral runner velocity	m/s
D_{wheel}	PCD of runner	m
d_j	Diameter of jet	m
N	Speed of turbine	rpm
□	Efficiency of turbine	-

REFERENCES

[1] Mane D.,Gadve H., Jankar S. (2018)"AnOverview On Osmotic Power And It's Scope In India"*International Journal of Advance research in Science and Engineering Vol. No. 07, Issue No. 03*

[2] YeshwanteR. "Generation of Electricity by Osmosis" *International Journal of ChemTech Research Vol.10 No.13, pp 219-224, 2017*

[3] Mishra A.(2013) "Osmotic Power Huge Source of Renewable Energy" *International Journal of Scientific & Engineering Research Vol.04, Issue 3*

[4] Oystein S. Skramesto, Stein Erik Skilhagen, Werner Kofod Nielsen "Power Production Based On Osmotic Pressure"

[5] Bilal A.(2013), , "Design Of High Efficiency Pelton Turbine For Microhydropower Plant" *International Journal Of Electrical Engineering & Technology (Ijeet)Volume 4, Issue 1 pp. 171-183*

[6] Adokar D., Patil D., Gupta A.(2013) "Generation of Electricity by Osmosis"*International Journal of Emerging Technology and Advanced Engineering* www.ijetae.com *Volume 3, Issue 3* Head of department, Lecturer, Final Year Student, Electrical, SSBT's COET, Bambhori, Jalgaon.