AN OVERVIEW OF OSMOTIC POWER GENERATION AND ITS SCOPE IN PAKISTAN

Syed Waqar Hasan[1*] and Syed Faraz Hasan[2]

[1]National Refinery Limited, Pakistan

[2]Department of Electrical Engineering, NED University of Engineering and Technology, Karachi

*email: waqar_hasan88@yahoo.com

ABSTRACT

The need of introducing innovative power generation methods is increasing rapidly worldwide. The conventional fuel driven methods not only require heavy financial investments, they have also been held responsible for many natural calamities faced by the human population. While the research on better utilizing the renewable resources such as wind, tidal and wave energy etc is underway, the Osmotic Power has been commercially introduced as a new fuel-free energy resource. The energy in the osmotic power is derived from the difference in salt concentration between the fresh water and the salt water. In this paper, we take an in-depth look into the technical details of the osmotic power generation. We identify some of the geographical locations alongside the country's coast that can be ideal for setting up an osmotic power station. We also evaluate the osmotic potential in the sea water on the coast of Karachi with the help of laboratory tests and mathematical estimation. According to our estimation, the osmotic potential in Karachi's sea water is comparable to that available in the first commercial osmotic power plant.

Keywords: Osmosis, Osmotic power plant, Power generation, Renewable energy.

1. INTRODUCTION

Pakistan is facing an energy crisis which is worsening every day. The difference between supply and demand is increasing at a regular pace, which drastically affects commercial and domestic activities. According to the latest figures reported in ref[1], the gap between supply and demand is between 3600-4000MW. This power shortage has resulted in frequent and elongated power break downs across the country. While the authorities consider getting increased supply from hydroelectric power generation and other fuel-driven sources, the need for increasing the installed capacity of the power system is plummeting rapidly. A power system is composed of three main components, namely, generation, transmission (and distribution) and utilization. For a power system to run efficiently, all the three sectors must perform satisfactorily. Utilization is one sector which has controlled to balance the supply and demand in the recent days. Closing the markets in early evenings and taking 2 days off in a week are tactics which aim at reducing utilization. The approach of reducing utilization to cope up with the energy crisis has serious drawbacks. It has severe economic consequences and most importantly, it does not solve the problem in the long run.

Many experts hold the transmission system responsible for losing a significant amount of generated power while delivering it to the consumers. The transmission and distribution system of the Lahore Electric Supply

Corporation (LESC), for instance, has become completely outdated. It faces dozens of transformer tripping even under normal load conditions[2]. Theoretically, the transmission line losses amount to about 40% of the generated power. Without undermining the need of an efficient transmission system, authors believe that even an efficient transmission system cannot bring things back to normal for the national power system. This is because the consumer load increases with the increasing industrialization and urbanization, which cannot be tackled just by improving the transmission system. We maintain that the generating capacity of the country must be increased in order to deal with the current energy crisis.

The country mainly relies on fuel-based power generation with the main fuels being the Natural Gas, Petroleum and Coal. Despite having reasonable coal and natural gas reserves in the country, much of the generated power comes from the furnace oil. Table I shows the contribution of different resources in generating electricity in Pakistan[3]. In contrast to the global trends, Pakistan is still using fuel driven methods to generate electricity. Today's world is rapidly switching towards the alternate energy sources in order to save the all important economy. For instance, the United Kingdom aims at providing one third of the country's energy demands from the renewable resources[4]. The trend is even more popular in Norway which not only supplies the country's power demands from the hydroelectric plants; it is also exporting electricity to the neighbouring countries. Very recently, Norway has recently started a new power plant called the Statkraft Power Plant that utilizes osmotic pressure to generate electricity[5]. In this paper, we give an overview of this state-of-the-art method of power generation and relate it with the opportunities of osmotic power generation in Pakistan.

The rest of this paper is organized as follows. Section 2 briefly describes the principles of osmotic power, followed by a brief discussion on the opportunities of osmotic generation alongside the coast of Pakistan in Section 3. Section 4 evaluates the osmotic potential in the sea water at the coast of Karachi. Conclusion is given in Section 5 while References are given at the end of the paper.

2. Principles of Osmotic Power

In a setup where a semi-permeable membrane separates the solution and solute, the pressure exerted by the solution on the membrane is known as the Osmotic pressure. Figure 1(a) and 1(b) show the solution and solute separated by a semi permeable membrane (permeable to solute) inside a container. Initially, as shown in Figure 1(a), same quantities of the solvent and solution are present in the container. The solute on one side tends to drift across the membrane to dilute the solution on the other side and hence increases the level of the solution inside the container. Consequently, a pressure difference is generated on one side of the container[6]. The membrane typically allows fresh water to pass through it and hence the fresh water is normally used as a solute in commercial installations[7]. The pressure difference P_{diff}, shown in Figure 1(b), is referred to as the Osmotic Pressure and can be used for generating electricity. This pressure is later imparted against the turbine blades to get renewable electricity.

Table I. Electric power contributed by different sources in Pakistan

	Power generated
Hydel	6500
Thermal (Gas and Oil)	13000
Thermal (Coal)	150
Nuclear	450

A conventional schematic diagram of the Osmotic power plant is given in Figure 2[8]. The plant requires abundant supplies of fresh and sea water to exploit the principle of osmosis. In Figure 2, the sea water is fed to Tank A after modestly pressurizing it using the pressure exchanger. Similarly, tank B is filled with the fresh water, which is separated from Tank A via a semi permeable membrane. Due to osmosis, the fresh water from Tank B diffuses into Tank A and further increases the fluid pressure inside Tank A. This pressure is imparted against the turbine which eventually produces mechanical power at its terminals. Some of the pressure from Tank A is fed back to the pressure exchanger, which is utilized in pressurizing the incoming sea water. Therefore, the energy required for pressurizing the sea water does not come from any external source. The turbine coupled with a generator eventually converts this mechanical power into electricity. A more detailed and illustrated block diagram of an osmotic power plant can be found in ref[9].

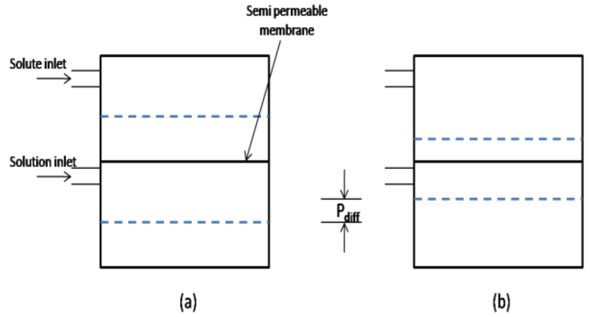

Figure 1. The principle of Osmotic Power

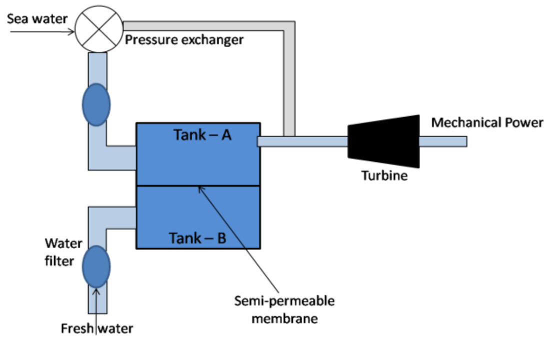

Figure 2. Schematic of an Osmotic power plant

For the optimum performance of the osmotic power plant, the selection of suitable membrane is a key factor. In the following, we highlight some of the issues related with selecting the appropriate semi-permeable membrane for the plant.

A. Semi-permeable Membrane

A semi-permeable membrane is also termed as the partially or differentially permeable membrane because it allows certain liquids to pass through while resisting the others. The process of diffusion across a semi-permeable membrane is also called the facilitated diffusion. The penetration rate of molecules through a semi-permeable membrane is a function of pressure, temperature and the concentration of molecules on both sides of the membrane, as given in Equation (1).

$$\gamma = f(P, T, \delta) \qquad (1)$$

where, γ is the penetration rate, P and T are the pressure and temperature in the container, and δ is the concentration of the molecules.

The permeability of the membrane and the tube diameter which contains it has significant impact on the osmotic power generated. While the membrane tube diameter has an inverse relation with the output osmotic power, on the other hand, higher the permeability of the membrane higher is the output power. The diameter of the membrane tubes must be selected carefully because they are subjected to high fluid pressures. Kulkarni et al.[10] have selected 10mm of membrane tube diameter, which can withstand a pressure of 100 bars. The work focuses on the design of only 100kW osmotic power facility, so larger membrane tube diameters may be selected for large scale plants.

3. Osmotic Power options in Pakistan

Pakistan has a reasonably large coastal belt spread across the south of Sindh and Balochistan touching the Arabian Sea. Since an osmotic plant requires abundant supply of fresh and sea water, the ideal locations for setting up these plants are spots where the rivers fall into the seas and oceans. Figure 3 shows Pakistan's coastal belt at the Arabian Sea and the rivers which fall into the sea. It is evident from the figure that several places provide an appropriate opportunity to set up an osmotic plant and reap the low-cost low-carbon benefits for generating electricity. Table II details Pakistan's rivers falling into the Arabian Sea and their salient features. Authors believe that considering these locations for setting up an osmotic plant can be fruitful for increasing the overall installed capacity of the nation.

Table II. List of major rivers falling into the Arabian Sea

River	Location	Features
Dasht	Gwadar District, Balochistan	Mirani dam being built
Hingol	Makran Coast, Balochistan	Part of Hingol National Park
Hub	Lasbela, Balochistan	Houses the Hub dam
Indus	Karachi port, Sindh	Key water resource for Pakistan

4. Calculating the Osmotic Pressure

Identifying the geographical locations is one requirement for an osmotic power plant. Another one is the ability of sea water to support osmosis. In this section, we give an estimated value of the osmotic pressure available from the sea water at the coastal belt of Pakistan. We have used a sample of sea water taken from the shore of Karachi in a previous work[11]; here we used the same sample to reflect on its potential for osmotic generation. Table III briefly highlights some of the main characteristics of the sample, out of which, we are interested in the Total Dissolved Solid (TDS) in the water and it's Temperature.

Figure 3. The Pakistani coastal belt showing several rivers falling into the sea (image taken from www.mapsofworld.com).

Table III. Characteristics of the sample sea water

pH	7.6
Total Dissolved Solids (TDS)	17500mg/L
Electrical Conductivity	29.4mS/cm
Temperature	23.7^{o}

An accurate way of calculating the osmotic pressure is by using osmometers that are commercially available. However, in order to avoid the financial issues, the theoretical value is also preferred. Equation (2) gives the theoretical formula for calculating the osmotic pressure of water containing solids.

$$\pi = i.\phi.C.R.T \qquad (2)$$

Where π is the osmotic pressure, i is number of ions produced from the dissociating solute, φ is the osmotic co-efficient, C is the concentration of solutes, R is the universal gas constant and T is the temperature.

Using the TDS and temperature values of the sample from Table III[12], the osmotic pressure that can be obtained from the Karachi's sea water comes out to be 13.722bar. The osmotic pressure in the Statkraft plant is around 12 bar[13]. Although the value estimated in this paper is theoretical, still, it is slightly more than the value originally achieved in the world's first osmotic power plant. An interesting future work would be to accurately calculate the osmotic potential available in the coastal belt of Pakistan so as to calculate the potential of generating electricity more accurately.

5. CONCLUSION

The identification of new generation methods is very important for Pakistan as the country faces the severe power crisis. In this paper, we have given an overview of an innovative power generation method, namely the osmotic power. In the first part of the paper, the main concept and methodology of exploiting the osmotic principles have been introduced. It has been discussed that the ideal location of setting up an osmotic plant is where the river water falls into an ocean or a sea. In the second part, we have shown that the southern coastal belt of Pakistan has several locations where an osmotic plant could be set up. According to our estimation, the sea water alongside the coast of Karachi has significant potential of generating electric power from an osmotic plant.

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