Capacitive Deionization based Water Desalination System using Solar Charge Controller

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Abstract

This paper focuses on addressing the issue of portable water scarcity, prevalent in various part of the world. There is a need to employ various expensive methods to transform the brackish water to standard potable water. The traditional methods of brackish water desalination deployed, namely the Reverse Osmosis Technique (RO) and the distillation processes are expensive in implementation and operation. This paper introduce a new concept "CAPACITIVE DEIONIZATION" to solve this problem. It is an energy efficient technology that provide an ideal alternative solution to this problem. In this technique remove the salt ions from the brackish water instead of removing pure water from brackish water like in the conventional reverse osmosis system. Thin film composite membranes of AEM Type-1 and CEM Type-1 are employed for collecting the respective ions which are separated by means of application of low value of dc voltage. It requires the usage of significantly less direct current energy for operation. This introduced system is enhanced by the utilization of solar energy so as to incorporate the most abundant renewable energy source available. This model which exhibits extreme potential of application mainly in remote locations which are devoid of proper access to conventional sources of energy and WHO specified standard potable drinking water.

Keyword- Capacitive Deionization, AEM and CEM Type Thin Film Composite Membranes

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I. INTRODUCTION

Water scarcity involves water shortage, water stress or deficits, and water crisis. The relatively new concept of water stress is difficulty in obtaining sources of fresh water for use during a period of time; it may result in further depletion and deterioration of available water resources. Water shortages may be caused by climate change, such as altered weather-patterns (including droughts or floods), increased pollution, and increased human demand and overuse of water. The term water crisis labels a situation where the available potable, unpolluted water within a region is less than that region's demand. Two converging phenomena drive water scarcity: growing freshwater use and depletion of usable freshwater resources. There is a need to employ various expensive techniques to transform the brackish water to standard potable water. The traditional methods of brackish desalination is deployed, namely the Reverse Osmosis Technique (RO) and Distillation processes are expensive in implementation and operation. Capacitive Deionization is an energy efficient technology that provides an ideal alternative solution to this problem. It is a novel technique which removes salt ions from brackish water instead of removing pure water from brackish water like in the conventional reverse osmosis system. Thin film composite membranes of AEM Type-I and CEM Type-I are employed for collecting the respective ions which are separated by means of application of a low value of dc voltage. It requires the usage of significantly less direct current energy for operation. This proposed system is enhanced by the utilization of Solar Energy so as to incorporate the most abundant renewable energy source available. This paper proposes a model which exhibits extreme potential of application mainly in remote locations which are devoid of proper access to conventional sources of energy and WHO specified standard potable drinking water.

II. BLOCK DIAGRAM

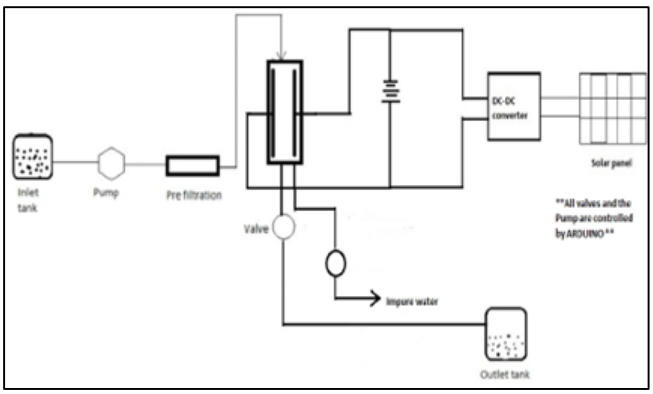

Fig. 1: Block Diagram of Proposed System

CDI is a novel desalination process that utilizes activated carbon electrode for the separation of saline solution to deionized solution Since a CDI process uses an adsorption reaction on the Electric Double Layer(EDL) on the electrode surface, the larger the specific surface area of the electrode, the more ions that can be removed. In this paper, prepared carbon electrodes using activated carbon and glutaric acid (GA) as a cross-linking agent and polyvinyl alcohol (PVA) as a binder. The physical and electrochemical properties of carbon electrodes are observed and analysed. Furthermore, the salt-removal for desalting experiment is also investigated. The brackish water from the tank is pumped into the Reverse Osmosis (RO) filter for the pre-filtering. Impure water is treated by a pre-filtration procedure which uses sand and activated carbon filters. The water is then pass to the CDI unit for desalination. Energy required for the process is supplied from the battery which is charged using an MPPT based solar charged controller. Battery can alternatively charge from ac source as well in absences of solar energy. The potable water is obtained at the outlet of CDI unit. The ARDUINO micro controller is used automatically controlled the whole CDI process. The program written in the ARDUINO which control two solenoid valves for the flow of pure and impure water at the outlet of CDI.

The solar charge controller is also included in this block diagram. The objective is to design a solar charge controller to for effective charging of the DC battery which is utilized to drive the CDI process. Solar panel that converts sunlight into DC electricity to charge the battery. This DC electricity is fed to the battery (it may be fed through a solar regulator for the safety of battery).The DC appliances can be powered directly from the battery. The low DC voltage from the lead acid battery is directly connected to the positive and negative electrodes in the CDI unit to drive the CDI process. In order to work our CDI unit, the 6v 1.5 watt solar panel used to charge the battery (4v) in the day light (it may be 1 or 2 hours) and this charged battery connected to the electrodes.

III. PRINCIPLE OF CAPACITIVE DEIONIZATION (CDI)

Capacitive Deionization (CDI) is a promising alternative technology in desalination which is particularly suitable for small scale inland brackish water desalination due to its lower energy demand and less maintenance requirements. CDI involves the removal of the salt ions from saline water, unlike most other technologies that aim to shift water, which accounts for the majority of the brackish water sample. Additionally, CDI requires low energy for operation and also the electrodes used can be easily regenerated. When voltage is applied between the two electrodes, get accumulated by the electro sorption process, where cations move into the cathode while anions are electros orbed in the anode. When the electrodes reach their adsorption capacity, depending upon the cell voltage. Discharge cycle is initiated by reducing or reversing the cell voltage, thereby releasing the salt as a concentrated stream. Hence no redox occurs and the process can easily be reversed when the electrical field is reversed to get rid of the salt accumulated in the membranes. This salt concentrated water is removed from the system with the help of a back flush system. The utilization of ion exchange membranes in the CDI process results in greater desalination performance compared to CDI implemented without the exchange membranes.

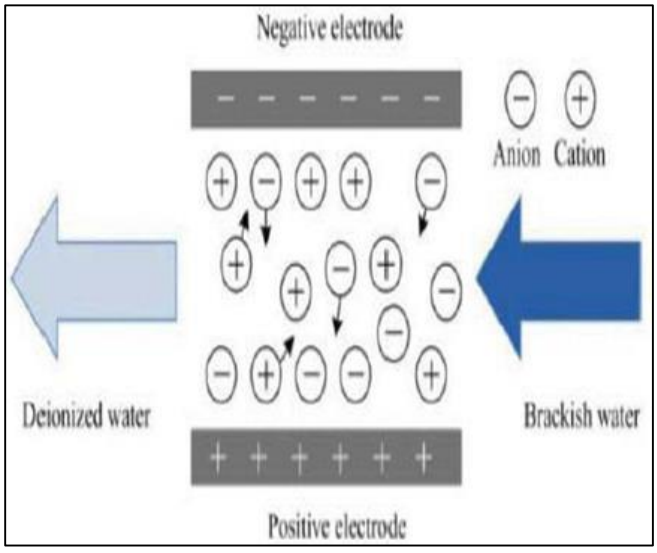

Fig. 2: Schematic of CDI process

IV. FABRICATION OF ELECTRODES

Capacitive deionization (CDI) is a desalination process in which one of the solution for handling the lack of fresh water. CDI is an electrochemically controlled method for reducing salt water become fresh water using a porous carbon electrodes. In the present study, we have prepared carb-on electrodes using activated carbon, carbon black, glutaric acid (GA) as a cross-linking agent and polyvinyl alcohol (PVA) as a binder. The physical and electrochemical properties of carbon electrodes are observed and analysed. Furthermore, the salt-removal for desalting experiment is also investigated.

Activated carbon powder (surface area 700 – 1400 m^2/g) from coconut shell which dried in a furnace at 80 degree centigrade over 24 h. PVA with molecular weight 60000 was purchased from Merck Co and glutaric acid (a cross-linking agent) was purchased from Aldrich Co. Graphite sheet used as a current collector. Aqueous PVA solution was prepared by dissolving 1 g PVA into 50 mL distilled water at 90 degree centigrade for 30 minutes, then a 20 g activated carbon is mixed together with PVA solution. At normal temperature, glutaric acid was added to the mixture to aid a crosslinking agent. The mixture was stirred for 4 h at room temperature. The slurry was then plated onto graphite sheet and allowed dry at room temperature for 4 days. Furthermore, the dried carbon electrodes were heated in a furnace at 120 degree centigrade for 1 h to cross-link the PVA with GA. SEM/EDX was used to observe the surface and cross-section of the carbon electrodes. The carbon electrode with surface area of 1 cm2 was inserted in water bath consist of an electrolyte solution 1 M NaCl. Meanwhile, a porous carbon rod was used as a counter electrode and Ag/AgCl electrode as a reference electrode. All measurements were maintained at 25 ± 0.1 degree centigrade. The salt-removal experiments were conducted by assembling a one pairs of carbon electrodes .Each a pair of carbon electrodes (6 cm × 8 cm) consisted of two parallel electrodes separated by a spacer. A solution with 0.1 M NaCl was pumped to the cell using pump (model SP-601) at a flow rate of 10 mL/min. All experiments were maintained at a potential of 3 V using a power supply Leader LPS 152.Desalination and regeneration were observed during the experiment for 60 min for each process.

Fig. 3: Fabricated electrodes

V. CONTROL EQUIPMENT'S AND COMPONENTS

A. Arduino Uno

Arduino uno is a micro controller board based on the ATmega328P. It has 14 digital input/output pins. In our CDI unit the arduino is used to control the solenoid valve, pump and MOSFET by using switching program in the arduino.

Fig. 4: Arduino Uno

B. Solenoid Valve

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid. It is used to control the flow of water in the system. As soon as the coil is electrical energized, a magnetic field is created which pulls the plunger up towards the centre of the coil. This open the orifice so that the medium can flow through. This is called a Normally Closed (NC) valve. When the solenoid is actuated, the orifice will be closed.

Fig. 5: Solenoid Valve

C. Solar Panel

Solar unit consists of a photo voltaic cell 6v.The solar cell is the input to the Capacitive Deionization Unit. Solar cell is an electrical device that converts the energy of light directly into electricity by the photo voltaic effect, which is a physical and chemical phenomenon.

The operation of PV cell requires 3 basic attributes,

- The adsorption of light, generating either electron-hole pairs.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit (CDI).

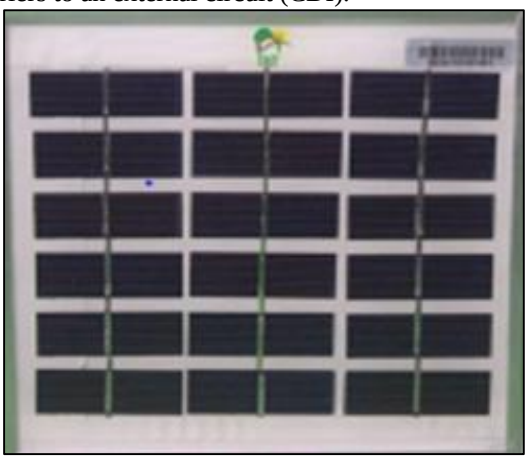

Fig. 6: Solar Panel

D. TDS Meter

Fig. 7: TDS Meter

It is used to measure the TOTAL DISSOLVED SOLIDS (TDS) of a solution. ie, the concentration of a dissolved solids. TDS meter display the TDS in parts per million (ppm). Ppm indicates 1 milligram of dissolved solids per kilogram of water.

VI. CONCLUSION

CDI is an energy efficient desalination technology that can benefit developing countries to produce potable water at very low cost. Concentrations up to 10 mg/liter can be desalinated effectively using CDI. CDI is beneficial compared to conventional desalination methods in terms of system operating parameters and economic feasibility. The prototype that we have presented can be modified for a large scale purpose which can yield good results. This Capacitive Deionisation is energy efficient technology that is bound to benefit developing countries primarily, since their water problems are more severe as compared to the developed world. Capacitive Deionization is an attractive option for many other TDS applications such as treating input water for cooling towers, point- of entry related water treatment and treating produced water from oil, gas mining and other mainstream industrial activities. This system provides a viable technological solution to the critical humanitarian problem of accessibility to potable water.

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