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Electrolysis-Based Seawater Desalination and Water Purification System

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Abstract

This project presents a method for separating seawater into its basic components using the process of electrolysis. The main aim is to address the growing need for fresh water by developing an efficient and eco-friendly technique for water purification. In this system, We send electricity through the seawater, which breaks water splits into two gases — hydrogen and oxygen gases while allowing the separation of salts and impurities.

The project involves designing and implementing an electrolysis setup using suitable electrodes, power supply, and sensors to monitor parameters such as voltage, current, temperature, and conductivity. To see how effective the system actually is analyzed based on water purification efficiency, energy consumption, and salt extraction capability.

Compared to conventional desalination methods like reverse osmosis, this method has some clear benefits such as simpler design and suitability for small-scale applications. However, challenges like energy requirements and electrode degradation are also considered. The results of this project aim to provide a practical and sustainable solution for seawater treatment and contribute to future advancements in water purification technologies.

Introduction

Water is something no living person can survive without, yet the availability of fresh water is becoming increasingly limited due to population growth, industrialization, and climate change. Although nearly 70% of the Earth's surface is covered with water, most of it is seawater, which you cannot drink straight from the ocean or domestic use because of its high salt content. Therefore, there is a growing need to develop efficient and sustainable methods for converting seawater into usable fresh water.

Traditional desalination techniques such as reverse osmosis and thermal distillation are popular choices, but they often require high energy, expensive infrastructure, and complex maintenance. These drawbacks make them a poor fit suitable for small-scale or low-cost applications, especially in rural or water-scarce regions.

Electrolysis is an alternative method that uses electricity to split water into hydrogen and oxygen gases while enabling the separation of dissolved salts and impurities. This this method could actually be more environmentally friendly and can run on clean energy sources such as solar power, making it a smart way to clean water without harming the environment.

This project focuses on building and creating an electrolysis-based system for seawater separation. It includes the study of system parameters such as voltage, electrode material, and processing time to optimize performance. The project also aims to evaluate the efficiency, energy consumption, and practicality of the system for real-world applications.

Materials

The stainless-steel plate is used as electrode plates. Dimensions of electrode plates 30×60×2 mm. The hydrogen production shell is made of PVC (polyvinyl chloride) material. The production shell is fully shield to avoid leakage of hydrogen gas during production process. KOH (potassium hydroxide) is a chemical used. KOH is mixed water and the electricity is passed into it. The KOH increases the electrical conductivity for hydrogen production.

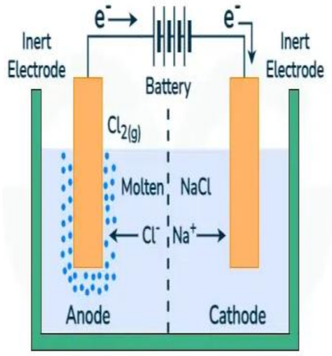

Fig 1: Electrode Plates.

PU (polyurethane) tube is used to transfer hydrogen from one place to another. Here a plastic can acts as storage can. The can is filled with water, this water helps to prevent backfire while performing test in a IC engine.

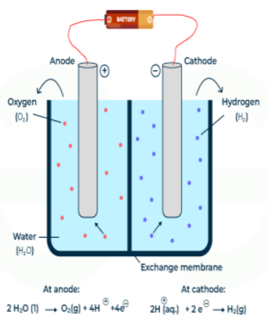

Fig 2: separation process of hydrogen and oxygen

Methodology

The methodology of this project involves the design, development, and testing of an electrolysis-based system for the separation of seawater into purified water and salts. The process is divided into three main stages: data collection, system development, and testing.

1. Data Collection Module

In this stage, various parameters required for monitoring the electrolysis process are collected using sensors. These readings include things like voltage, current,water conductivity, temperature, and the volume of purified water obtained. Sensors such as voltage and current sensors, conductivity sensors, temperature sensors, and flow meters are connected to a microcontroller (Arduino or Raspberry Pi). The collected data is recorded in digital form and stored in CSV or Excel format. Preprocessing techniques are used to remove noise and arrange the data for further analysis.

2. System Development Module

The system is developed using an electrolysis cell, electrodes, DC power supply, and a microcontroller. When electricity runs through seawater,electrolysis takes place, splitting water into hydrogen and oxygen gases, while salts and impurities are separated. The microcontroller controls the power supply and regulates voltage and current based on sensor feedback. Software is used to calculate system efficiency, including water purification rate, salt separation efficiency, and energy consumption. A graphical user interface (GUI) is also developed for real-time monitoring and control of the system.

3. Testing and Analysis Module

In this stage, the system is tried out in different situations such as varying voltage, salinity, and duration of electrolysis. Sensors are calibrated before experiments to ensure accuracy. The cleanliness of the water is checked by measuring how much salt and other substances are still dissolved in it (TDS). Multiple trials are conducted to check consistency and reliability. The results are compared with standard values, and statistical analysis is performed to evaluate system performance. Based on the observations, system parameters are optimized to improve efficiency and reduce energy consumption.

4. Calculation

Total production of gas from one plate (H2O)

Hydrogen = 0.035 lit/min

Oxygen = 0.017 lit/min

So, by adding the hydrogen and oxygen we get, = 0.035 + 0.017

Total gas = 0.052 lit/min.

The amount of hydrogen generated from the experiment is about,

Here N = no of electrode plates = 2 × 0.052

Amount of hydrogen generated = 0.104 lit/min.

Calculation for the parameters in table 2; The voltage and ampere were calculated using the digital multi-meter and amp meter. The amount of 104 ml of hydrogen in seconds is using the stopwatch. The KOH grams are varied like 2g, 4g, 5g, 6g and 8g mixture with water and measuring it at which time it achieves 104ml using stopwatch. Here the measure values are in milli litres.

We know that the total amount of hydrogen generated = 0.104 litre
Total amount of hydrogen × 1000
= 0.104 × 1000
= 104 ml.

Table 1: Experimental Results of Hydrogen Production During Seawater Electrolysis

S.No	Amount of Water (mL)	Amount of KOH (g)	Voltage (V)	Current (A)	Amount of Hydrogen Produced (mL/sec)
1	1000	2	12	1.7	104/54
2	1000	4	12	3.4	104/45
3	1000	5	12	4.4	104/33
4	1000	6	12	5.0	104/26

Literature Review

Budiyanto, E.; Salamon, S.; Wang, Y.; Wende, H.; Tüysüz, H. Phase How separating certain elements inside tiny cobalt iron oxide wires can make them better at producing oxygen Reaction Activity. *JACS Au* 2022, *2*, 697–710. (1) *This article reveals the role of phase segregation and boundaries in cobalt–iron oxide for OER. The in situ electrochemical Raman spectroscopy captures the phase transformation from CoO to the defective Co_3O_4 spinel structure during OER*.

Yu, M. Q.; Moon, G. H.; Castillo, R. G.; DeBeer, S.; Weidenthaler, C.; Tüysüz, H. Dual Role how tiny silver particles attached to a specially structured cobalt oxide material can help produce oxygen more efficiently using electricity. *Angew. Chem., Int. Ed.* 2020, *59*, 16544–16552. (2) *This article demonstrates the dual effect of silver species on the OER performance of mesostructured cobalt oxide. Metallic silver particles enhance the conductivity of materials, while well-dispersed silver oxide clusters endow cobalt oxide with the capability of iron uptake from the alkaline electrolyte.*

Yu, M. Q.; Weidenthaler, C.; Wang, Y.; Budiyanto, E.; Sahin, E. O.; Chen, M. M.; DeBeer, S.; Rudiger, O.; Tüysüz, H. Surface Boron tweaking tiny cobalt oxide crystals to make them work better at producing oxygen through electricity. *Angew. Chem., Int. Ed.* 2022, *61*, e202211543. (3) *This article presents a facile synthetic methodology for the preparation of mixed boron–cobalt oxide structures. The presence of boron oxide was found to prevent the sintering of cobalt oxide nanoparticles at higher temperatures and improve their OER performance.*

Yu, M. Q.; Li, G. W.; Fu, C. G.; Liu, E. K.; Manna, K.; Budiyanto, E.; Yang, Q.; Felser, C.; Tüysüz, H. Tunable e_g Orbital Occupancy in Heusler Compounds for Oxygen Evolution Reaction. *Angew. Chem., Int. Ed.* 2021, *60*, 5800–5805. (4) *This research article shows the potential of Heusler compounds as a new class of OER electrocatalysts whereby e_g orbital occupancy was found to significantly influence the OER activity of the compounds*.

Proposed system

The proposed system is a Water Electrolysis Monitoring **System** designed to efficiently monitor and control the electrolysis process in real time. The system aims to improve safety, efficiency, and accuracy during hydrogen production through electrolysis by continuously tracking key parameters such as voltage, current, temperature, and gas (hydrogen/oxygen) output.

In this system, sensors are connected to a microcontroller-based unit (such as Arduino/ESP32) to collect real-time data from the electrolysis setup. The measured parameters are processed and displayed on an LCD/OLED screen and optionally transmitted to a cloud or mobile application for remote monitoring. This allows users to observe how well the system is working without needing to touch it, reducing risk and improving convenience.

Additionally, the proposed system includes threshold-based alerts. If any parameter exceeds safe operating limits (for example, excessive current or temperature rise), the system triggers warnings through buzzers or notifications and can optionally shut down the power supply to prevent damage or hazardous conditions.

The system is designed to be low-cost, scalable, and suitable for laboratory also small-scale industrial applications. By integrating real-time monitoring and control, the proposed system enhances the efficiency of electrolysis while ensuring operational safety and reliability.

Flow chart

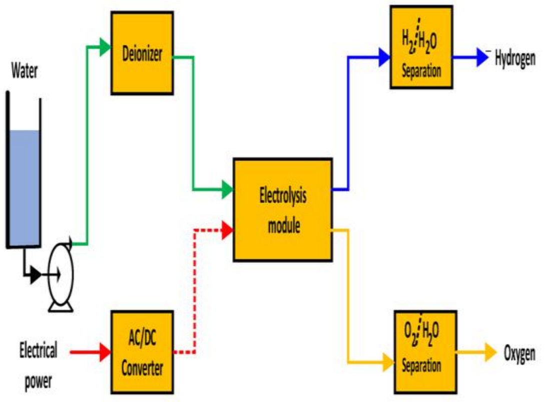

Fig 3: Block diagram

System Requirements

1. Hardware Requirements

- ESP32 Development Board

Acts as the central controller. It collects sensor data, processes it, and sends it to display and/or cloud platform via Wi-Fi.

- Voltage Sensor Module

Measures the input voltage supplied to the electrolysis cell for monitoring power stability.

- Current Sensor (ACS712 / SCT-013)

Detects current flow through the electrolytic cell to analyze power consumption and efficiency.

- Temperature Sensor (DS18B20 / LM35)

Monitors electrolyte temperature to prevent overheating and ensure safe operation.

- Electrolysis Cell (Glass/Plastic Container with Electrodes)

The main setup where water is split into hydrogen and oxygen gases.

- OLED / LCD Display (I2C preferred)

Displays real-time parameters such as voltage, current, and temperature.

- Relay Module (Optional but Recommended)

Used for automatic ON/OFF control of power supply during abnormal conditions.

- Buzzer / LED Indicators

Provides alerts for unsafe conditions such as high temperature or overcurrent.

- A DC power supply delivers a steady and controlled flow of electricity required for electrolysis process.
- Connecting Wires and Breadboard / PCB

Used for circuit connections and integration.

2. Software Requirements

- Arduino IDE / PlatformIO

Used for programming and uploading code to ESP32.

- Embedded C / C++

Core programming language for sensor interfacing and control logic.

- ESP32 Wi-Fi Libraries (WiFi.h, HTTPClient.h, etc.)

Used for enabling IoT-based data transmission.

- IoT Platforms (Blynk / ThingSpeak / Firebase / MQTT Broker)

Used for real-time remote monitoring and data logging.

- Serial Monitor / Arduino Serial Plotter

Used for debugging and local data visualization.

UML Diagram

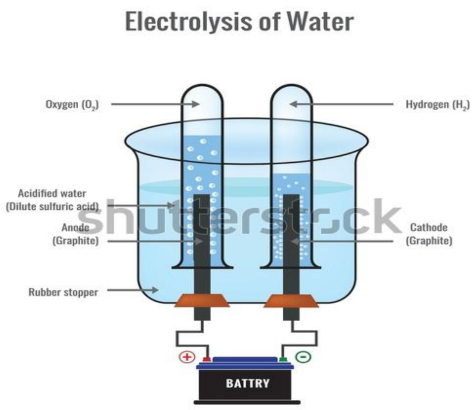

Fig 4: Hardware block diagram

Conclusion

The proposed Water Electrolysis Monitoring System using ESP32 successfully provides an efficient and reliable solution for real-time monitoring of the electrolysis process. By integrating sensors such as voltage, current, and temperature sensors with the ESP32 microcontroller, the system ensures continuous measurement and analysis of critical parameters involved in hydrogen production.

The implementation of IoT capabilities through ESP32 enables remote monitoring of data via Wi-Fi, improving accessibility and reducing the need for manual observation. Additionally, the system enhances safety by incorporating alert mechanisms such as buzzers, LEDs, and optional automatic shutdown using a relay when abnormal conditions are detected.

Overall, the system improves the efficiency, safety, and control of the electrolysis process while maintaining a low-cost and scalable design. It is suitable for laboratory experiments, educational purposes, and small-scale hydrogen production research applications.

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