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PIC-CONTROLLED OXYGEN AND LIGHT GENERATION USING RENEWABLE RESOURCES

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Abstract— **In this paper, a model is proposed to harness solar energy for generation of oxygen and light. The solar panels convert daylight into electricity, which is used for decomposition of waste water into oxygen and hydrogen. Oxygen is released in the air to breathe and hydrogen is stored as fuel. Light Emitting Diode (LED) lights, driven from the generated electricity are used to radiate light during night. The automation and control for the processes is provided by an integrated Peripheral Interface Controller (PIC).**

This paper is intended to provide a model, which can be implemented to meet oxygen requirements and lighting demands of the cities in an eco-friendly manner. The paper also discusses the challenges to proposed technology and provides suggestions to overcome them

Index Terms— Solar panel, PIC microcontroller.

I. INTRODUCTION

Trees naturally convert carbon dioxide into oxygen, an element that is necessary for survival of almost all living organisms on Earth. However, in this day and age, humans are cutting down billions of trees for paper, furniture, building supplies, and other purposes. The number of trees is decreasing while the population of humans is growing rapidly. As a result, the oxygen levels are falling while the concentration of carbon dioxide in air is increasing.

Air pollution is a major issue for almost all countries across the world. Air pollutants can lead to respiratory illness in humans and animals, create acid rains and deplete the ozone layer. Actions such as carpooling, reducing the use of fossil fuels, and simply turning off a light when leaving a room are ways to reduce harmful carbon dioxide levels in our atmosphere. But the most effective natural sources that eat away carbon dioxide are the trees. Trees take in carbon dioxide and release oxygen during photosynthesis. Therefore, the loss of trees in cities has had devastating results on the composition and purity of the air we breathe.

Heavy levels of carbon dioxide gases in cities create thick smog and affect the natural ecosystem. These concentrated levels of carbon dioxide gas create a hostile environment for trees and plants making it difficult for them to grow properly. All these problems necessitate us to design a solution to either overcome them or reduce their effects on human population. And that is the solution that we propose to provide through our model. Our model is capable of generating and releasing pure oxygen in the atmosphere using renewable resources. In addition to it, hydrogen gas is produced which is stored and has potential to be used as fuel later. We believe that such a design will not only aid in supplying pure oxygen to urban environment but also meet lighting demands of developing and developed cities.

II. LITERATURE REVIEW

In today's world, our environment is facing a lot of stress as a result of increasing population and development. The problem is more severe in developing nations like India. The need of the hour is to implement more eco-friendly projects/plants that can provide advanced technology solutions, preferably by means of renewable energy and have least or no negative impact on environment.

Many research laboratories around the world are working towards the same objective to implement innovative and environment friendly industrial design solutions. K.S. Lackner's work includes the demonstrating and improving passive methods to remove carbon dioxide from the atmosphere in the context of addressing climate change[1][2]. The ability to combine innovative design with advanced technology, with sensitivity to environment, make Artemide the ideal vehicle in the development of this technology, conceived by Ross Lovegrove, with the collaboration of Sharp Solar, world's leading manufacturer of solar cells.

The biggest challenge is to implement this technology in Indian cities as we know the population is a lot more in this country and hence the environment is more polluted. We gathered basic knowledge for this project from earlier models and developed a new prototype that has the potential to fulfill the oxygen and lighting requirements in cities. Many scientists and researchers are still working on the same topic and coming up with ideas like artificial leaves that would convert carbon dioxide directly into oxygen. Our designed and implemented “artificial tree" produces breathable oxygen using sewage water and simultaneously acts as street light during night. It also displays physical parameters such as temperature and light intensity.

III. Functional Units

The working components that formed the basis of our model are listed under this section. A general description of each component or unit is followed by the specification of the same used in our device.

A. Photovoltaic Modules

Photovoltaic (PV) modules collect energy from sun and convert it directly into electricity. A PV cell is made of a semiconductor material, usually crystalline silicon, which absorbs sunlight. This energy directly gets converted into electrical energy, which is why they are efficient and convenient to use. Most PV modules contain a top protective layer, two specially treated layers of silicon and a polymer backing layer. In our model, we used six solar modules each made of polycrystalline cells.

B. Light Dependent Resistor

Light Dependent Resistor (LDR) is a component that is sensitive to light. An LDR or photo resistor is made up of semiconductor with high resistance. Cadmium Sulfide is popularly used. In our model, we used single 5mm size ceramic LDR.

C. Thermistor

Thermistor is a resistor whose resistance is dependent on temperature. There are two types; those with a resistance with increase in temperature (positive thermal coefficient) and those with a resistance with decrease in temperature (negative thermal coefficient). We used single 5mm size, negative thermal coefficient thermistor in our model.

D. Light Emitting Diode

It is a two lead semiconductor light source. It is a p-n junction diode which emits light when it gets activated. With high power LED lights, it is possible to save a high percentage of energy. They have low maintenance costs. We used three strips of LED lights (blue color) in our model.

E. Electrodes

Electrolysis of water is decomposition of water into oxygen and hydrogen gas due to an electric current being passed through water. This technique was used to obtain hydrogen fuel and breathable oxygen. We used a jar container with two graphite (carbon) electrodes for our model.

F. Liquid Crystal Display

It is a flat panel display that uses light modulating properties of liquid crystals. LCDs are energy efficient and have a wide range of applications. We used a 16x2 LCD display screen with voltage requirement of 5V.

G. Battery

Battery is a device consisting of two or more electrochemical cells that convert chemical energy into electrical energy. We used two rechargeable lead acid batteries with nominal voltage of 6V each and charge capacity of 4 Ampere-hours each.

H. Relay

A relay is an electrically operated switch. An electrical contact is a component found in relays. Normally Open (NO) contact is a contact that is open or in a non-conductive state when it, or device operating it, is in non-energized state. Similarly, Normally Close (NC) contact is in a closed or conductive state in non-energized state. A total of four relays were used in the circuit.

I. Peripheral Interface Controller

Peripheral Interface Controller (PIC) is a type of microcontroller component that is used in the development of electronics, computers, robotics and similar devices. They are inexpensive, easy to use and can be reprogrammed. PIC is also known as Programmable Interface Controller or Programmable Intelligent Controller. It was the brain of our model. We used PIC16F877A (368 bytes RAM) for our model.

IV. Design and Development

The hardware arrangement of the model along with its working will be discussed under this section followed by insights into development and implementation of the project.

A. Hardware Design and Working

- The solar panels were placed on two foot tall aluminum rods. We used six rods each carrying one solar module. The arrangement of rods was likewise bonsai tree so that solar panels could trap maximum solar energy in the form of sunlight.
- The solar energy was converted into electrical energy by PV modules. This energy was used to charge the rechargeable batteries. We used two batteries (6V each) connected in series to give us a total voltage of 12V. The diodes were connected in circuit in such a way that they prevented the reverse flow of energy, i.e., flow of electricity from batteries to solar modules.
- A plastic jar was placed next to the aluminum rods. The jar contained two graphite (carbon) electrodes to carry out electrolysis. We used drinking water for electrolysis by mixing it with small amounts of sulfuric acid because electrolysis of pure water occurred very slow or not at all. The acid acted as a catalyst in separation of oxygen and hydrogen from water.
- The identification of gases produced by decomposition was done by collecting these gases in two different test tubes and lighting each with a matchstick. One test tube made a pop sound. It was confirmed that this test tube contained hydrogen gas because hydrogen gas is highly flammable. The other test tube contained oxygen. Oxygen supported combustion but did not produce a pop sound.
- The PIC microcontroller performed all the controls in the system. It was programmed with help of PIC SIMULATOR IDE, an application which provides integrated simulator, PIC basic compiler, assembler, de-assembler and debugger.
- An LDR was used to control the activity of LED lights. LDR gave us the value of intensity of light (lux). When

the reading of the measured value fell below the set point value, the LED lights glowed. However, when the reading of measured value exceeded the set point value, the lights stayed off. The set point value was kept as 100lux. The set point value was fixed or adjusted by programming the PIC microcontroller. A magnetized relay was used for on-off purpose of LED lights.

- A thermistor was used to sense the temperature of the surroundings. It was necessary to keep the temperature in check because high temperatures could be fatal as electrolysis involves production of hydrogen gas. As soon as the measured thermistor reading exceeded the set point value, the electrolysis would shut down. The set point value was set at 40 thermistor reading. The on-off control was again achieved with the help of relay (NO) and PIC microcontroller.
- A third relay (NC) was used to start or stop charging of battery. Whenever the voltage coming from the solar panels fell below minimum set point value (10V) or exceeded maximum set point value (14V), the NC relay opened and the charging stopped.
- An auxiliary relay was connected in the circuit for future accommodations. Suppose, it was decided later that mobile phone charger be installed in the model, in that case auxiliary relay would come into play.
- The 16*2 LCD screen was connected to the PIC controller. A 16*2 LCD screen has 2 rows with capacity of 16 characters each. We used this LCD screen to display battery voltage (volts), temperature (thermistor reading), light intensity (lux) and timer (seconds). The PIC controller was programmed in such a way that it displayed these parameters simultaneously for five seconds. As the timer counted five seconds, the first advertisement was displayed for a period of five seconds. Now, after ten seconds from the start, the second advertisement was displayed. After fifteen seconds, the third advertisement. And after 20 seconds, the cycle repeated.
- TTL USB cable was also connected to the microcontroller. It acted as an interface between the computer and the microcontroller. It could be used to display messages on LCD screen during emergency at any instant of time.
- The potential divider circuits were created to fulfill voltage requirement of each component.

B. Development of System

a) Problem Definition Stage: The problem definition stage was the first stage of our project. The aim and concept of the project was finalized.

b) Designing Block Diagram: At this stage, we developed the whole circuit and categorized it into different parts. The study of individual parts was helpful in understanding the concept and working of an integrated system. It also simplified entire debugging and testing process.

c) Implementing Circuits and Components: This was actual implementation of circuit of each block. At this stage, each separately designed block was finally integrated into a complete working system.

d) Developing Algorithm for Software: To get the logical flow of the program, the development of algorithm was necessary. The complete system was analyzed and algorithm was organized in such a manner that one could understand complete working of system and software.

e) Writing Actual Code for PIC: After development of algorithm and flowchart, we created a program in ANSII C language for PIC 16F877A microcontroller so that it could understand the instructions.

f) Compiling the Code: The code was implemented on computer with the help of Keil program. Keil is a computer aided program to simulate the working of microcontroller in real time without burning the actual IC. We simulated and compiled our program for error checking. After removing several compiling errors, the program was converted into machine language (Intel hex format).

g) Burning Hex file into PIC: At this stage, the compiled hex format file was burned into PIC16F877A microcontroller.

h) Testing and Running: We tested our project for actual working after loading the software into the microcontroller. Any errors found were removed successfully. This was the final stage of development of our project.

C. Implementation

- The project required a lot of hardware work and some amount of software work. It was a challenge to build a perfect model so as to present a perfect picture of what our project actually aims to do.
- The compilation of components like LDR, relays, PIC, etc., on Printed Circuit Board (PCB) was the most important part. Any error at this level could damage the components or lead to undesired results.
- Before writing a program for the microcontroller, it was necessary to set a few limits or values for some parameters in the project such as timer, battery limits, temperature limit, and light sensing limit.

V. RESULTS

A. Power Output of Solar Panels

It was observed that the solar panels absorb enough energy to charge the batteries. The total power output of solar modules was calculated to be 2.4 watts. The explanation is given below.

- Voltage and current output of single solar panel = 4V/100mA.
- Voltage and current output of three solar panels connected in series = 12V/100mA.
- Total voltage and current output by paralleling two series combinations = 12V/200mA.

$$\text{Power (W)} = \text{Current (A)} \times \text{Voltage (V)} \quad (1)$$

From equation 1, we get total power output of solar modules as 2.4 watts.

B. Charge Capacity of Solar Panels and Batteries

The total energy supply of solar modules and batteries was calculated in terms of electric charge (Ampere-hour).

- Battery rating of single battery = 6V/4Ah.
- Total output of two batteries connected in series = 12V/8Ah.
- Total energy output of solar modules (one hour) = 0.2Ah.

From above calculations, it was concluded that it would take solar modules forty hours at full working (maximum output) to fully charge a dead battery. But in reality, the lead-acid battery does not charge linearly with time and hence it would take more than 40 hours. However, the case of batteries becoming fully discharged is highly unlikely during normal functioning and was never observed in our experiments. Once the batteries were sufficiently charged, the electrolysis took place smoothly for an entire day. Even when it was a cloudy day, the battery worked properly. The battery had enough charge to carry on for a couple of days without input from solar panels. Under normal circumstances, the batteries were charged enough during daytime to carry on function throughout the night.

C. Rate of Electrolysis

The rate of electrolysis was observed to be same throughout the day whether it was day or night, sunny or overcast. The rate does not depend on percentage of charge unless the battery is fully discharged. In our model, the electrolysis would stop only at full discharge of battery or if the battery voltage fell below 10V or exceeded 14V, which was improbable under normal circumstances.

D. Amount of Hydrogen and Oxygen Produced

During electrolysis, it was noted that the production of hydrogen gas was more than that of oxygen. This was confirmed by equation 2 (decomposition of water). Remember that the use of sulfuric acid is essential for electrolysis. The pure water decomposes very slowly or does not decompose at all.

$$2\,H_2O\,(l) \rightarrow 2\,H_2\,(g) + O_2\,(g) \qquad (2)$$

The amount of gas produced depends on the pressure and concentrations. It also depends upon the amount of current supplied to the electrolysis jar. Assuming standard conditions, we calculated the amounts of oxygen and hydrogen produced in one hour on decomposition of water by a battery when no other component was connected to the battery. Electric charge in 12V (6V + 6V) battery = 8Ah. We know that,

$$\text{Charge (C)} = \text{Current (A)} \times \text{Time (s)} \qquad (3)$$

Therefore, from equation 3, it is clear that if we run 8A current for 1 hour, we get 28,800C of electrical charge. Now, a mole of electrons has a charge of 96,500C, so that means 28,800/96,500 = 0.30 moles of electrons will flow. Now, two electrons have to flow for each water molecule to be divided so 0.30 moles of electrons split 0.15 moles of hydrogen and 0.075 moles of oxygen. But, 1 mol gas = 22.4L of gas. Therefore, 12V x 8A = 96 watt hour of electricity can split 2.7 gram of water into 3.36L of hydrogen and 1.18L of oxygen. Note that the above calculations were done under ideal conditions in which the electrodes draw all the current from battery at 12V. Suppose, electrodes (electrolysis process) draw 1A of current from the batteries, it would mean that the batteries have the capacity to run for duration of 8 hours.

Table 1 represents amount of hydrogen and oxygen gas produced for different levels of battery charge. The quantities of hydrogen and oxygen produced were calculated in Liters. The amount of water decomposed was calculated in grams. The Battery Charge column shows the percentage of battery charge when the electrolysis started.

Table 1
Amount of oxygen and hydrogen gas produced on decomposition of water by 8Ah battery

Battery Charge (%)	*Water decomposed (g)*	*Hydrogen gas (L)*	*Oxygen gas (L)*
100	*2.7*	*3.36*	*1.68*
75	*1.9*	*2.46*	*1.23*
50	*1.3*	*1.68*	*0.84*
25	*0.63*	*0.78*	*0.39*
0	*0*	*0*	*0*

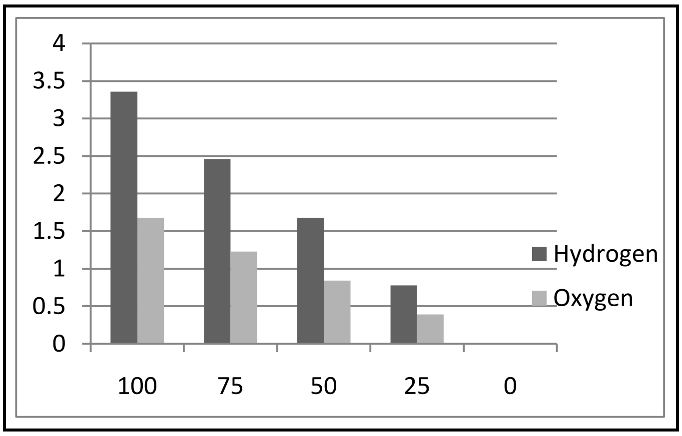

Fig. 1. Gas Production (L) v Battery Charge (%). Y-axis shows amount in liters and x axis shows battery charge percentage

Fig. 1 represents ‘Gas production (Liters) v Battery Charge Capacity (%)’ graph. It was confirmed that the rate of production of hydrogen gas is double to that of oxygen gas for any battery and does not depend on the electrical charge of the battery. It was clear from the calculations that a higher Ampere-hour battery would produce higher amounts of oxygen and hydrogen. Figure 2 shows electrolysis jar with two graphite electrodes.

E. LED lights

The LED lights functioned properly and lit up automatically as soon as the light intensity reading dropped below 100lux. The lights turned off immediately as the light intensity exceeded 100lux. Figure 3 shows LED lights in ON state.

F. LCD display

The LCD screen successfully displayed advertisements, battery voltage, timer, light intensity and temperature reading of thermistor. Figure 4 shows LCD screen displaying battery voltage (Batt), timer (S), light intensity (L) and thermistor reading (T), clockwise from top.

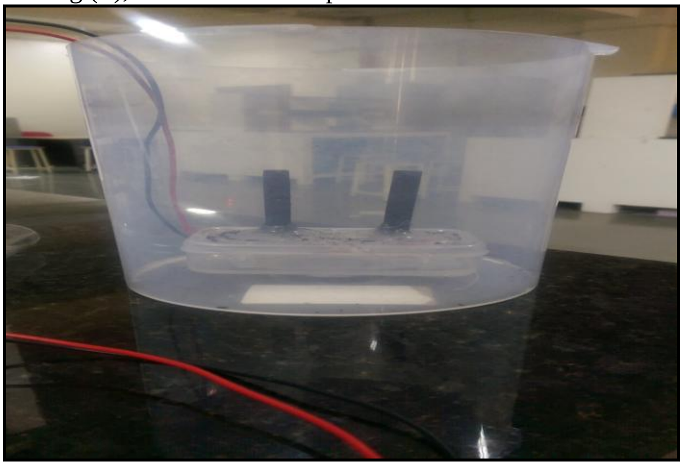

Fig. 1. Electrolysis jar containing two graphite (carbon) electrodes

Fig. 1. LED Lights in on state when light intensity dropped below100lux

Fig. 2. LCD Screen showing battery voltage (Batt), timer (S), light intensity (L) and thermistor reading (T), clockwise from top

VI. Discussion

The structure of artificial tree should ideally be made of recycled materials because recycling helps to reduce the pollution caused by waste.

We used six solar panels in our model but in real world applications, more number of solar panels must be used to generate greater power.

The sewage water should be used for electrolysis. The sewage water naturally contains acidic substances which are ideal for electrolysis. A membrane must be installed between the supply and the electrolysis jar to remove solid sediments and other impurities from the sewage water.

In reality, around sunset time, as soon as the light intensity will drop down below set point value, the LED lights will glow acting as street lights.

A fair amount of oxygen gas and hydrogen gas was generated by electrolysis which makes these gases suitable for breathing and storing respectively. Currently, humans are not producing hydrogen gas commercially by electrolysis, however, in future when the hydrogen reserves run out of hydrogen fuel, this method for hydrogen production can come into use commercially.

During monsoons or persistent overcast weather, the batteries might not get sufficiently charged. So we need a substitute for solar modules to charge the batteries. Hammocks are one way of producing power. They can be installed between two adjacent trees to generate electricity. The kinetic energy produced by hammocks would get converted into electrical energy with the help of an auxiliary circuit. Similarly, other methods can be used depending on location, budget and other factors. Research and testing of alternate methods is required.

Heat can be stored more easily than electricity, so panels made of solar thermo-photovoltaic (STPV) cells can generate electricity even at night, assuming they hold on to the heat that they absorbed during the day. This field needs more research so that these cells are commercially profitable.

VII. Applications and Advantages

The model has various applications and advantages as listed below.

A. Applications

a) Oxygen Generation: The actual model will produce breathable oxygen gas in cities or areas with less number of trees or no trees. It will provide better levels of oxygen in the atmosphere.

b) Hydrogen Generation: The model will produce hydrogen gas which can be stored during electrolysis and used later as a fuel for vehicles or other purposes.

c) Street Lights: The useful device will also act as a decorative item in the streets. The LED lights in the night will lit up the sky and provide a beautiful spectacle.

d) Gadget Charger: The actual model can be used to charge the gadgets like mobile phones and laptops.

e) Advertisements: Advertisements will be displayed on the LCD screen. This will attract the sponsors.

f) Temperature and Light Intensity Display: The physical parameters such as temperature and light intensity will be displayed. Time can also be displayed.

B. Advantages

a) Low Cost: Running and maintenance costs of this device are very low.

b) Eco-friendly: The device is eco-friendly as it uses solar energy as basic source of energy.

c) Easy Installation: The lack of wiring minimizes disruption caused to roads or nearby locations during installation. Solar street models can be erected at almost all locations.

d) Self-Sufficient: Power outages have no impact on street lighting.

VIII. Conclusion

Our designed and implemented “artificial tree" produces oxygen, but without the need for planting, soiling or watering. Such a design is can be implemented usefully in cities, where there are insufficient trees and the concentration of carbon dioxide gas in air is alarmingly high while levels of oxygen gas are low. In addition, our model also fulfils street lighting requirements of cities. As discussed in Results, our implemented design is capable of producing 1.68L of oxygen and 3.36L of hydrogen from 2.7g of water and 8Ah battery in one hour. The solar panels can successfully produce 2.4 W of electricity which is stored in battery and used to light up LEDs and carry out electrolysis.

The model is environment-friendly, saves money, is cheap to use and can be installed anywhere. Although the initial installation will require planning and resources, we believe the long-term benefits would be totally worth it.

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