Residential Electrolyzer Optimized with Pulse Width Modulation and Magnetism

Brennan Angus, Matthew Beausoleil, Jacob Cooper, Wyatt Groves, Austin Jerrolds, Conner Sanders
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, TN
bjangus42@tntech.edu, mbeausole42@tntech.edu, jjcooper42@tntech.edu,
wlgroves42@tntech.edu, acjerrolds42@tntech.edu, cdsanders43@tntech.edu

I. Introduction

Brown's gas has the potential to be a viable energy solution. This project will construct an electrolyzer that will measure the efficiency of the electrolysis process. The constraints of this project are largely defined by specification, ethics, standards, and potentially broader impacts. The conceptual design of this project will focus on defining all possible constraints of the project as well as the breakdown of the project into smaller sections so that the team can conceptualize it.

A. A Fully Formulated Problem

The system is expected to be a fully functioning electrolyzer that is able to measure the energy efficiency of the electrolysis process. The constraints that define the system are listed below.

A System shall accurately measure the electrical efficiency of the electrolyzer.

A.1 The system shall accurately read electricity usage and gas output.
- Use sensors to determine how much electricity is used to create an amount of Brown's gas.

A.2 System shall quickly take in sensor readings and compute efficiency rating.
- An external device should be able to take the sensor readings as inputs and compute a specified output.

B The System shall abide by all safety standards outlined by OSHA, NFPA, and those that the team feels are necessary.

B.1 The system shall not use cast iron fittings for any piping, fitting, or tubing.[1]
- This comes from OSHA standard 1910.103, which states that cast iron is susceptible to corrosion from hydrogen

B.2 The system shall have an emergency stop button.
- This comes from NFPA 79 which states that when an emergency stop button is pressed, all dangerous actions will stop without creating new hazards.[2]

B.3 The system shall comply with NFPA 70 wiring and power consumption.[3]
- This constraint is important to ensure the system is able to operate in a safe manner.

B.4 The system shall shut off if the pressure and temperature of the cell come close to ignition conditions of Browns Gas.

B.5 Safety controls shall be programmed on their own controller.
- This is a team-decided standard that aims to avoid any confusion with the programming of the system as a whole.

B.6 All systems that are monitored by safety sensors shall have redundancy.
- The redundancy will be to ensure that the system is properly handled when the system is malfunctioning.

C The system shall automatically replace water in the cell housing.
- This keeps the electrodes submerged in the electrolyte to ensure the highest levels of efficiency can be attained. This constraint is derived to help with obtaining higher efficiencies.

D This system shall ensure that the maximum volume of liquid inside the electrolytic cell does not exceed 95% of the cell's storage capacity.
- This constraint ensures that the system does not overflow and cause damage to other components in the device. This constraint derives from the need to ensure all components remain undamaged.

E This system shall not have unstable fluctuations in voltage of more than 10 percent greater or less than the rated voltage of the device.
- High voltage fluctuations from the system can cause inaccurate or poor efficiency calculations.
- This constraint is also derived from a desire to ensure safety while the device is being operated.

F The material of the electrolytic cell housing shall not be reactive with Potassium Hydroxide.
- This is to allow for the adaptability of the system to varying electrolysis setups. One is taking advantage of Potassium Hydroxide. This constraint is derived from the broader impacts.

G The material of the electrolytic cell should be transparent or translucent.

- This is to allow us to see what's happening inside of the cell, and to observe functionality visually.

H The pulse generator's output should be rectified

- The pulse generator's output needs to be rectified to set up future use wherein the gases can be separated. Otherwise, each electrode would be producing hydrogen and oxygen due to the unrectified waveform.

I System shall be set up in a well-ventilated area.

- This constraint comes from ethical considerations. The safety and health of the user is an engineer's top priority. The area needs to be well ventilated in the off chance of a leak or pressure in the system needs to be released.

J System shall not exceed 50 PSI.

- This originates from not wanting to over-pressurize the system to help prevent premature ignition in the cell housing.

II. Ethical, Professional, and Standard Consideration

A. *Ethical*

Engineers have a duty to make sure that the safety of the user is top priority. The system has inherent dangers due to the nature of the project. The team's responsibility is to keep the system as safe as possible for the user.

Another ethical consideration is the effects that the system could have on the environment as any leak on the cell tank could lead to dangerous chemicals being released.

B. *Standards*

The system generates hydrogen and oxygen gas and each gas when handling will need to use its standards laid out by OSHA 1910.103 and 1910.104. These standards constrain us to how the corresponding subsystem should be set up.

NFPA 79 talks about the standards and regulations in place for industrial systems. The system was not originally designed for an industry environment, but it will act as a guide as electrolysis is primarily used in an industrial setting.

Apart from the abnormal standards, the system shall also comply with NFPA 70 electrical for installing and designing each of the subsystems.

C. *Broader Impacts*

The project is subject to broader impacts that are both positive and negative impacts that must be considered. Ideally, this system is efficient enough to be placed in homes giving them access to hydrogen gas. It could be used in third world countries to give them access to resources that they do not normally have.

Another impact the system could make is on the military. It is usually looked at for the generation of hydrogen, but the system would be making oxygen gas. The need for oxygen on a submarine needs to be as efficient as possible. Some inherent danger comes from the handling of the hydrogen gas as it is an asphyxiant gas and needs to be expelled from the submarine[4].

A negative impact would be on oil companies as there could be less demand for fossil fuel products such as oil, natural gas, and gasoline. This would have the potential to reduce the workforce in the industry as the demand for natural gas to heat homes and kitchen appliances would decrease.

Electrolysis is used in industrial environments to generate various chemical gasses. With minor adjustments, this system could make these industrial processes easier and more cost-effective. This could drive the manufacturing cost down which could drive cost down in industries that rely on these chemical gasses.

III. Block Diagram

A. ***Controller System***

This subsystem will encompass all of the measurements and calculations for all the subsystems required by the constraints of the project. This block will consist of a microcontroller to perform the computations, and multiple sensors to read various characteristics of the systems.

1) *Microcontroller*
   The microcontroller will handle all of the calculations and data readings. This unit will read the hydrogen content, flow rate, water level, and electricity usage as well as any other sensor data that needs to be displayed.

   Input: Power Consumption, Brown's Gas Content

   Output: Efficiency Calculations

2) *Watt Meter*
   This sensor will be responsible for measuring how much power the system is using. This is important for making the efficiency calculations. The sensor needs to measure how much power only the cell and safety system use, not the components of the efficiency calculations.

   Input: System power input

   Output: Wattage Usage or Power consumption

3) *Hydrogen Sensor*
   This sensor will be used to estimate how much gas the system produces. This is the other half of the efficiency calculations.

   Input: Gas Output of the Electrolyzer

   Output: Digital Signal to Represent the Amount of Hydrogen Generated

4) *Flow rate Sensor*
   This sensor will be used to estimate the throughput of

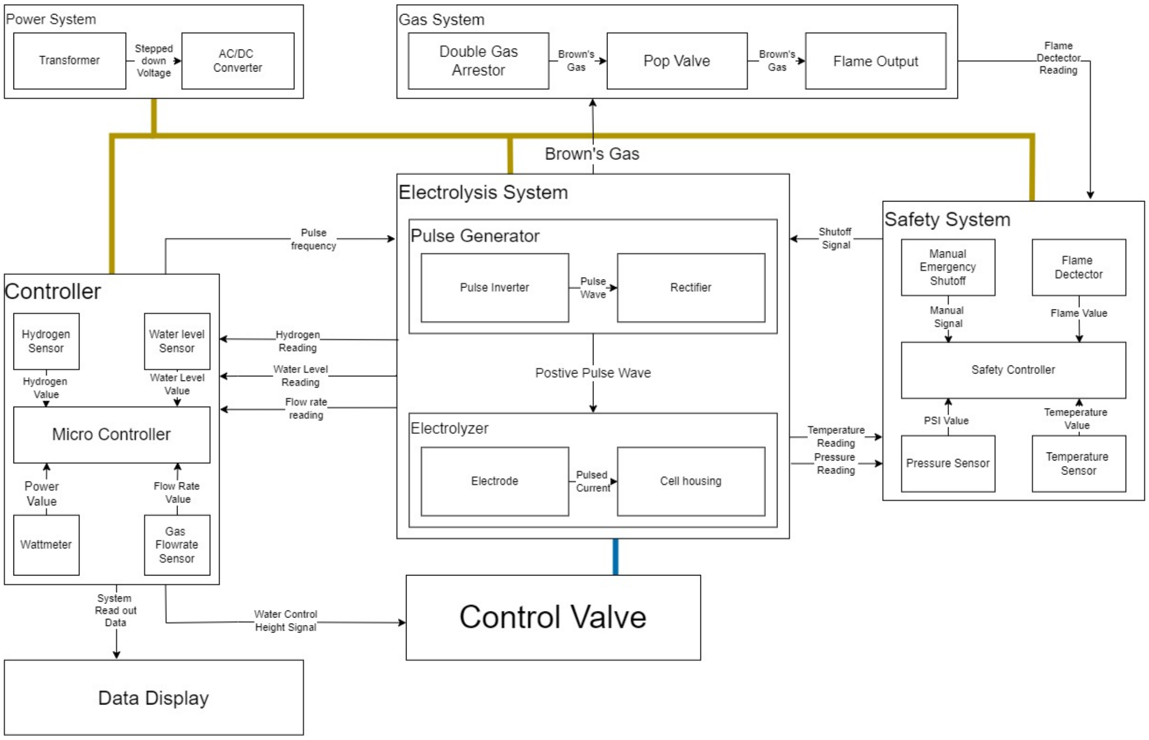

Fig. 1. Block Diagram

gas. This will then be used to adjust the pulse frequency to try to maximize efficiency.

Input: Gas Output of the Electrolyzer

Output: Digital Signal to Represent the Amount of Hydrogen Generated

5) *Water level Sensor*
The water level sensor will measure the water level of the cell and communicate with the water control valve through a microcontroller to open and close as appropriate.

Input: Water Level

Output: Value of Water Level

6) *Display Output*
The display of this system will communicate to a user the efficiency of the system as well as any necessary sensor data.

Input: Microcontroller Readings and Computations

Output: Text Output of Efficiency Rating, Power Consumption, Hydrogen Content, Sensor Readings

This system will comply with constraints **A**, **A.1**, **A.2**, **C** and **D**. This subsystem is important to running various other. This subsystem will also follow constraint **B.2** for input-output wiring.

B. *Safety System*

This system will control all the sensors that will shut off the pulse generator. It is imperative that the system shuts off the pulse generator so gas generation stops.

1) *Safety Controller*
This system will take in all the safety sensors and if any were to be read as too high it would turn off the pulse generator until it is in safe conditions again.

Input: Pressure Reading, Temperature Reading, Emergency Stop Signal, Flame Detector

Output: Shutoff signal to the pulse inverter

2) *Pressure Sensor*
The pressure sensor will notify the safety controller when the system reaches 40 psi. This is to ensure that we never reach the pop valve pressure unless this sensor is malfunctioning.

Input: Power Consumption, Brown's Gas Content

Output: Efficiency Calculations

3) *Temperature Sensor*
The temperature sensor will make sure the system does not reach temperatures that auto-ignite the gas. It will send the readings to the safety controller to determine if it is too high.

Input: Water Temperature Reading

Output: Temperature Value

4) *Flame Detector*
The detector will monitor the flame output, and output a high voltage if a flame is present and a low voltage if one is not. This will ensure the system is on only when there is a flame present. This does mean there needs to be a delay before the sensor starts working as it needs a moment to start generating the gas.

Input: UV/IR Radiation

Output: Flame Present Signal to the Safety Controller

5) *Manual Shutoff Switch*
This switch will be away from the system to allow the user to safely shut the system off. This just be a simple switch that takes priority

Input: User Input (button press)

Output: Shutoff Signal to the Safety Controller

This system will abide by constraints **B, B.2, B.3, B.5** and **B.6**. The safety subsystem will be required to accept inputs from various sensors, a flame detector, and a manual shutoff switch to relay a signal that shuts off the pulse generator.This shutoff will ensure that electrolysis is halted, and gas production is stopped if any part of the process becomes unsafe.

C. *Electrolysis System*

The electrolysis system takes in DC current and water to generate Brown's gas. The use of pulse width modulation and permanent magnets will enhance the efficiency of the system.

1) *Pulse Generator*
The pulse generator will be used to create a voltage across the electrodes in order to trigger the electrolysis. The optimal pulse amplitude and pulsing rate for the highest efficiency will be determined.

a) *Pulse Inverter*
The Pulse Inverter will generate a pulsing current for the electrodes. Depending on the gas throughput, the frequency of the pulses shall change to help maximize efficiency.

Input: DC Current

Output: Pulse Wave

b) *Rectifier*
This will take the Pulse wave generated at the pulse inverter and only give the system a positive peak. This allows for the system later down the road to be redesigned for separating the gas.

Input: Pulse Wave
Output: Positive Pulse Wave

2) *Electrolyzer*
The rate of gas production through electrolysis must be matched to the combustion rate to prevent gas accumulation. This typically involves adjusting the current and voltage appropriately to produce gases at a controlled rate.

Input: Water, Positive Pulse Wave
Output: Brown's Gas

a) *Electrolytic Cell Housing*
The cell housing is where the electrolysis will be taking place. This is where the water and rectified current pulse wave will be used. Also, this is where most of the sensors will housed but the read-out will go to the controller subsystem.

Input: Water

Output: Brown's Gas

b) *Electrode*
The electrodes are how the system drives the current into the electrolyte. It will be important to have electrodes with a rather large surface area. This allows for more of the electrolyte to take part in the reaction.

Input: Positive Pulse wave

Output: Hydrogen Gas, Oxygen Gas

The electrolysis system will abide by constraints **F, G, H, I** and **J**. It will be restrained to operate in a way that prevents hazards like excessive pressure.

D. *Gas System*

This system is all about handling the gas once it is generated. Since there is no storage in the system as it is too dangerous. There needs to be precautions in the event that something would not be going accordingly.

1) *Double Gas Flashback Arrestor*
The Double Gas Flashback arrestor is a way for the system to prevent any combustion from going back into the cell housing. This part of the gas system is more of a safety measure.

Input: Brown's Gas

Output: Brown's Gas

2) *Pop Valve*
The pop valve is a redundancy for the pressure in the system. The pop valve should only release pressure if the pressure sensor can not properly detect the over-pressure. This shall be set at the max pressure, 50 psi, as anything more leaves the system in a more dangerous state.

Input: Brown's Gas

Output: Brown's Gas

3) *Flame Output*
Since the system will have no storage, the gas will need to be as it is generated. That being said the system will just burn the gas as it will convert Brown's Gas into water vapor leaving no harmful gas.

Input: Brown's Gas

Output: Flame

The gas system will abide by constraint **B.6**, and **J** in a mechanical manner. This ensures even when the power to the system is off there is safety measure still in place.

E. Water System

The water subsystem will be the system controlling all water flow to the electrolytic cell. While the main purpose of the water subsystem is to allow water to be present to perform electrolysis, the water level must be kept within certain limitations for optimal efficiency.

1) *Water Control Valve*
The water control valve will be a simple system to allow water to be input into the cell, similar to a hose or faucet.

Input: On/Off Signal from Microcontroller

Output: Water

The purpose of this subsystem is to automate the process of adding water to the system. It will ensure that the electrodes are submerged at all times, as shown in constraint **C**. It will also not allow any water to be input into the system if it detects water levels too high, as shown in constraint **D**. This will take some of the hassle away from the user, providing a smoother experience.

F. Power System

The power subsystem will be designed in such a way that most devices will pull from a common supply, with commercially available power adapters being used for the main conversion from AC to DC, and buck converters being used as necessary on a per-system basis.

1) *Transformer*
The pulse inverter will not be powered by the transformed voltage. Instead, it will be powered directly by DC voltage, with no transformation taking place.

Input: 120/240 V, 60 Hz Power

Output: Transformed 60 Hz Power (On a per system basis)

2) *AC to DC Converter*
A separate AC-to-DC converter will be used for the pulse inverter. It will take in power directly from the 120/240 V wall socket.

Input: Transformed 60 Hz Power

Output: DC

All aspects of power will follow the constraints as described by **B.3** and **E**.

IV. Timeline

The gant chart in 2 shows the projected deadlines for the project. It is more front-heavy to allow for more time later to figure out unforeseen issues. The electrolysis system needs to be designed first as it is the center of the project, but shortly after the other subsystems can be designed. There is some time left out towards the end of the first semester, giving the team time to attend finals and other projects going on at the time as well.

V. Conclusion

The conceptual design of an Electrolysis Brown's gas generator is comprised of 6 main subsystems. These systems include a power system, an electrolysis cell, a controller system, a safety system, a water intake system, and a gas output system. This conceptual design acts as an outline for the system as a whole, without deciding on the exact components that will be used to create the system.

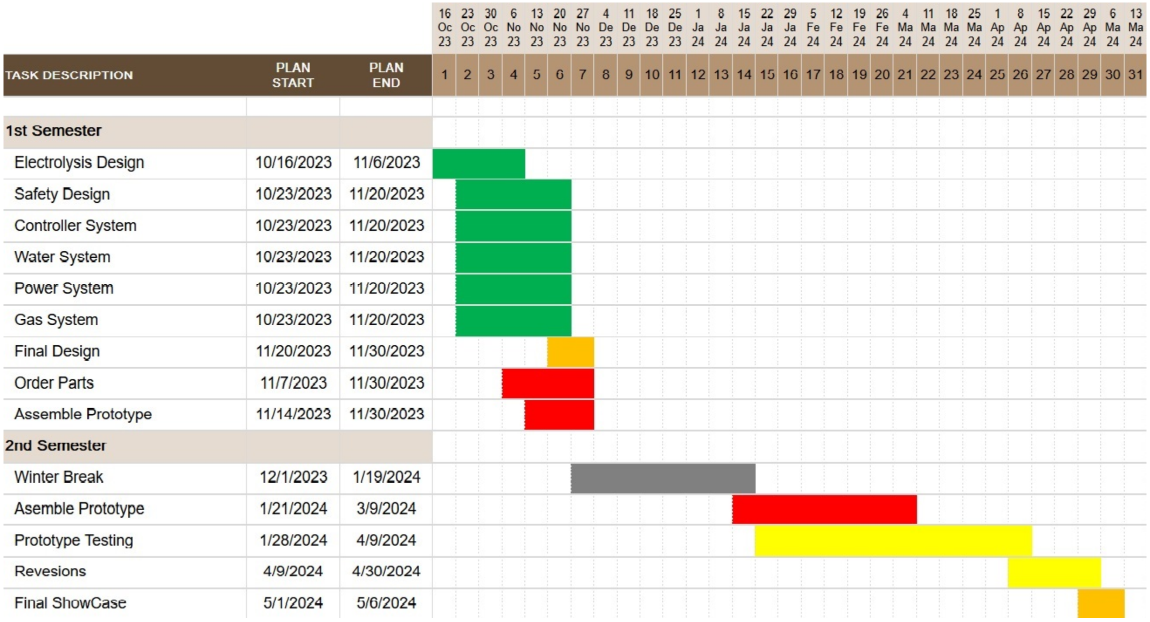

Fig. 2. Timeline

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