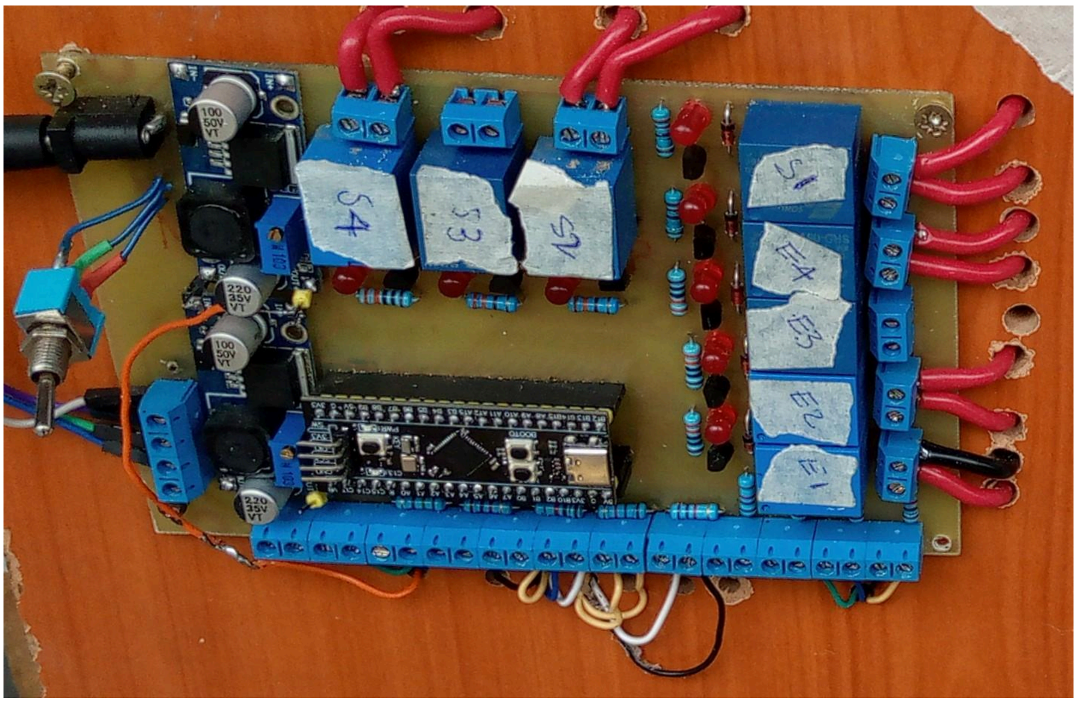
Electrolysis Control System

The electrolysis control system serves the overall function of automating the electrolysis process.

Design overview

Below is the physical board of the control system



The above board was designed to control 4 different electrolysis chambers independently and has the following key components:

- **1 STM32F411CEU6 microcontroller unit -** This is a 32 bit microcontroller with a clock speed of up to 100MHz. This serves to control other components on the printed circuit board (PCB).
- **8 relays** - 4 relays are used to control 4 electrolysis chambers and other 4 relays control 4 solenoid valves that allow electrolyte solution into the chamber.
- **8 float switch sensor interfaces -** Float switches are connected to these interfaces. 2 float switches have been used per electrolysis chamber; one to measure the minimum level of electrolyte in the chamber and one to measure the maximum level.
- **1 pressure sensor interface -** The pressure sensor requires a special 4-20ma interface. 8 interfaces were required but one was realisable due to the expensive nature of the device. A gas hub was therefore used to collect gas from respective chambers and store it in a reservoir to be sensed by this device.

- **1 gas flow rate, concentration and temperature sensor interface** - The device that measures gas flow rate, concentration and temperature requires a UART interface for communication with the microcontroller. Similarly, 8 interfaces were required but one was realisable due to the expensive nature of the device. A gas hub was therefore used to collect gas from respective chambers to be sensed by this device.
- **1 display interface** - Currently a display interface is supported over two protocols, I2C and SPI. The display connected will serve to display system operation parameters and inform an operator of the current state of the system.

Control System Operation

Automating the electrolysis process involves continuing and/or stopping the electrolysis process against system operation parameters.
These operation parameters include:

- Electrolyte level in the electrolysis chamber
- Temperature of gas realised
- Concentration of particular gas realised
- Flow rate of gas realised
- Pressure of gas in the storage area
- Rate of change of such system parameters

These operation parameters give an inclination of the general operation of the control system.
The control system device is intended to be powered on and left to operate without further manual interaction.
Good operation without manual interaction ensures safety of personnel since production of oxygen and hydrogen in very large quantities poses a lot of risk to life.
However, there are still unavoidable manual interactions in this first prototype which can be catered for with further improvements in the control system. By control system this means the controlling device and its surrounding elements These will be mentioned further along
Control system operation will be better explained with the following assumption in the setting

Control System Setting / Installation

The setting of the control system assumes:

- Availability of DC power (which can be supplied by a solar panel and battery system)
- Direct connection to electrolyte source

Startup Operation

Upon powering on of the control system, the system checks if the level of electrolyte in all the electrolysis chambers is at maximum. For each chamber, if the level is not at maximum, the respective solenoid valve will be opened to let in electrolyte from the electrolyte source.

Once the electrolyte level is at maximum, this information will be conveyed to the microcontroller unit through the respective float switches and the solenoid valves will be closed by powering them off.
The system then checks if gas pressure is at maximum at the gas reservoirs using the pressure sensors.
If gas pressure is at maximum the system will not commence the electrolysis process and will inform an operator through the display of the need to change the gas reservoirs.
If gas pressure is not at maximum, the system commences the electrolysis process by powering the electrodes using the respective relays.

Continuous Operation

On successful startup the system will continually check for normal system operation through the use of limits of safe operation of the system properties.
These limits of safe operation are as of now approximations but accurate values can be obtained through stress testing the system.
Limits of safe operation as with any system will require some startup time after successful start.
The startup time is unique per system designed and is determined empirically.
Current limits of safe operation of the first prototype of the system are:

- Max startup time to expect good rating system parameters - 3 minutes
- Minimum electrolyte quantity per chamber - as determined by float switch position in chamber
- Max gas temperature - 70 ^{0}C
- Minimum gas concentration - 80%
- Gas flow rate - 30 L/min i.e 20 L/min hydrogen, 10 L/min oxygen
- Max gas pressure - 10 bar
- Maximum allowed rate of change of each system parameter - 30%

With the defined limits above, the control system will have good judgement on whether to continue or stop the electrolysis process.
The list of limits and their accuracies continues increasing with system improvements further leading to more defined and deterministic system operation.
This is important in fault analysis of the system when subject to different conditions. These conditions may include larger scale systems among others.

Control System Current Flaws and Areas of Improvements

As with all systems there exists the need to improve the system further upon examination of what has been realised thus far.
Current flaws and areas of improvement of the current system include:

1. Bad board design

The system as it is does not realise the full potential of the microcontroller unit it uses. This is because of the following:

- Interfaces of the microcontroller unit that can perform complex operations have been used up by components that require basic operation. Relays and float switches require basic operation and such an operation can be delegated to a simple IC which can be controlled by the main microcontroller. A good board design will cater for such. With such an improvement more gas pressure sensors and gas flow rate sensor interfaces can be operated by the microcontroller unit
- Currently the only way the board can inform a plant operator is by the use of the display. This is not the best way of conveying information. Systems that provide automation functions are best equipped with components that allow connectivity through GSM, GPRS or Wi-Fi. A good board design will cater for such.

2. Over the Air Updates

Currently, the system lacks a GSM/GPRS or Wi-Fi module that allows connectivity. This is a major drawback as it makes such a system lack over the air updates.
When provisioning thousands of such systems, firmware improvements of the systems will not be possible manually as the systems will be in different locations. Furthermore, manual intervention also will pose the system to risk due to errors made by manual operations. A good board design will cater for such.

3. Bad choice of components

Currently, the system measures the level of electrolyte solution in the chambers by use of float switches inside the chambers. These float switches are prone to corrosion over time by the electrolyte solution and further increase the complexity of building an electrolysis chamber.
Use of non-invasive means of measuring electrolyte solution such as lasers will improve the electrolyte chamber design simplicity and will ensure the system components last a long time.
Non-invasive here has been used to mean not requiring to be put inside the electrolysis chamber.