Automated Hydroponic System Design with Minimal Human Interaction

Author: Omar X. Santos De Jesús

Advisor: Prof. Julio Noriega, PhD

Mechanical Engineering Department

Abstract

The design of an automated hydroponic system follows from the need of having a system that works through difficult situations. A situation involving a power outage is considered a major problem since the plants in the hydroponic should not be kept without water for more than a couple of hours. If it occurs, the plants will not be able to be harvested and it would result in economic and time loss. Having an automated system would prevent this disaster and would provide the owner some help by showing what it needs. For different types of hydroponics there are different methods of application, but they all follow the same needs. For easy application and better understanding of the system, electronic integration with Arduino is used. This design covers the basic needs of the hydroponic system while providing easy manufacturing and integration.

Introduction

Hydroponics give more control to the person growing the plants while using less water and having a design where oxygen is not blocked by the soil. William F. Gericke, professor at the University of California, Berkeley, discussed his research in February 1937, about growing tomato vines only using water and nutrients and had better results than growing them with soil [1]. Although a hydroponic system is a great way to grow plants, the person maintaining the system should always be aware that it is running correctly without any problems. Some factors to look after would be the water level of the tank, the pH level, water pump, and oxygen pump working correctly. If one or more of these factors are failing, the plants cannot be harvested and there would be economic and time loss.

Background

The Nutrient Film Technique (NFT) was created by English scientist Allen Cooper in the 1970's, which helped commercial hydroponics expand globally [1]. It consists of a system which pumps nutrients as a film of water through a channel, which is at an angle. The nutrient solution in the reservoir should have a required pH level between 5.6 and 6.2 [2]. An example would be to have water soluble fertilizer with NPK of 5-18-30. A hydroponic design will be developed to notify the person the pH level of the solution and the water level of the tank using different sensors. These will indicate the person if the system needs more solution mixture for pH balance or if the nutrient solution level in the reservoir is low. These sensors will be connected to an Arduino Mega, which is a type of programmable microcontroller, to obtain the information.

Problem

Since the main problem in Puerto Rico is power outages, this design provides a solution for some time until the power comes back. Many people who have hydroponics have had this problem and their plants have died during power outages, losing weeks of work. The system will show the pH level of the nutrient and water level while being self sufficient during a power outage.

Methodology

The design of the system has a 27 gallon tote, LCD screen, Arduino Mega, water pumps and oxygen pump. The circuit design for powering the system works with a $12V_{dc}$ power supply, a 12V 12Amp-hr battery and a power switch adapter module.

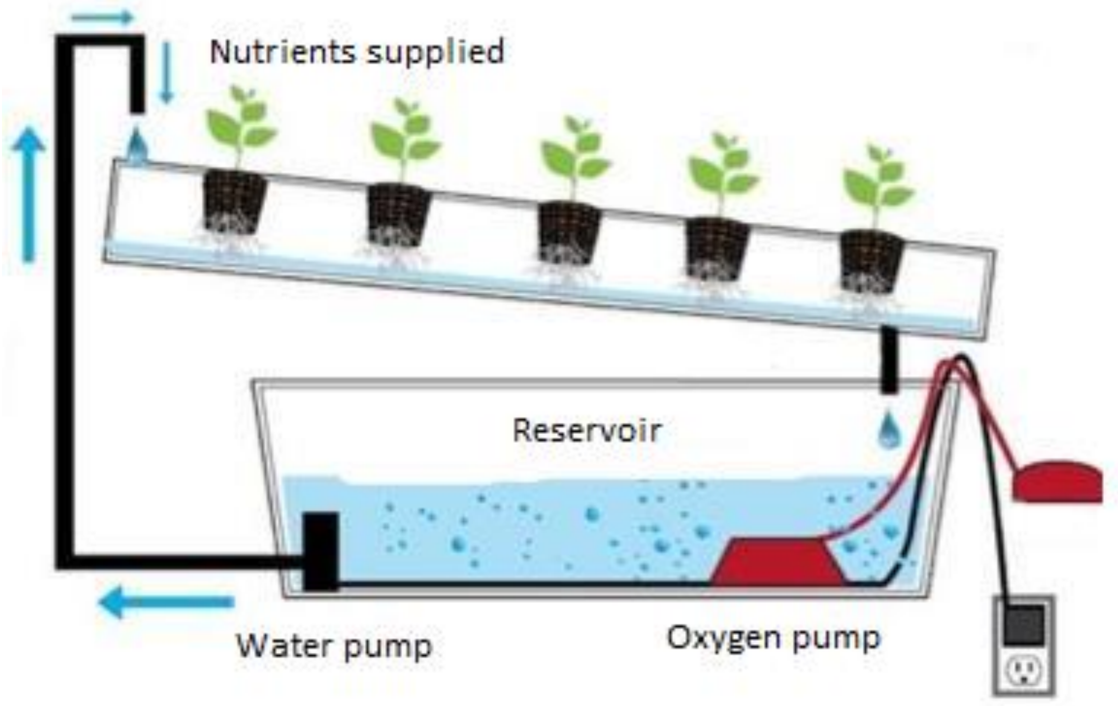

Figure 1: NFT Hydroponic

All Ponics helped by providing their lettuce starter kit which includes the nutrients to make the solution following the size of the tote, germination table and romaine lettuce seeds. The nutrients consist of water-soluble fertilizer (8-15-36), calcium and magnesium. Once these nutrients are mixed in the water it gives a pH balance of 6.5. The lettuce seeds are put through the process of germination. After everything is added, the system is put to the test for days with the power supply and then with only the battery to observe for how long the system runs in case of a power outage. The pH probe sensor used with the Arduino is compared to the water quality meter sensor bought to verify if it works accordingly. The water flow of the system is measured to be 3.5L/min. The flow rate of the solution should be less for the PVC pipe, about 0.35L/min, for optimal growth. A flow rate of 0.24L/min will then be compared to the results obtained from the 3.5L/min flow rate.

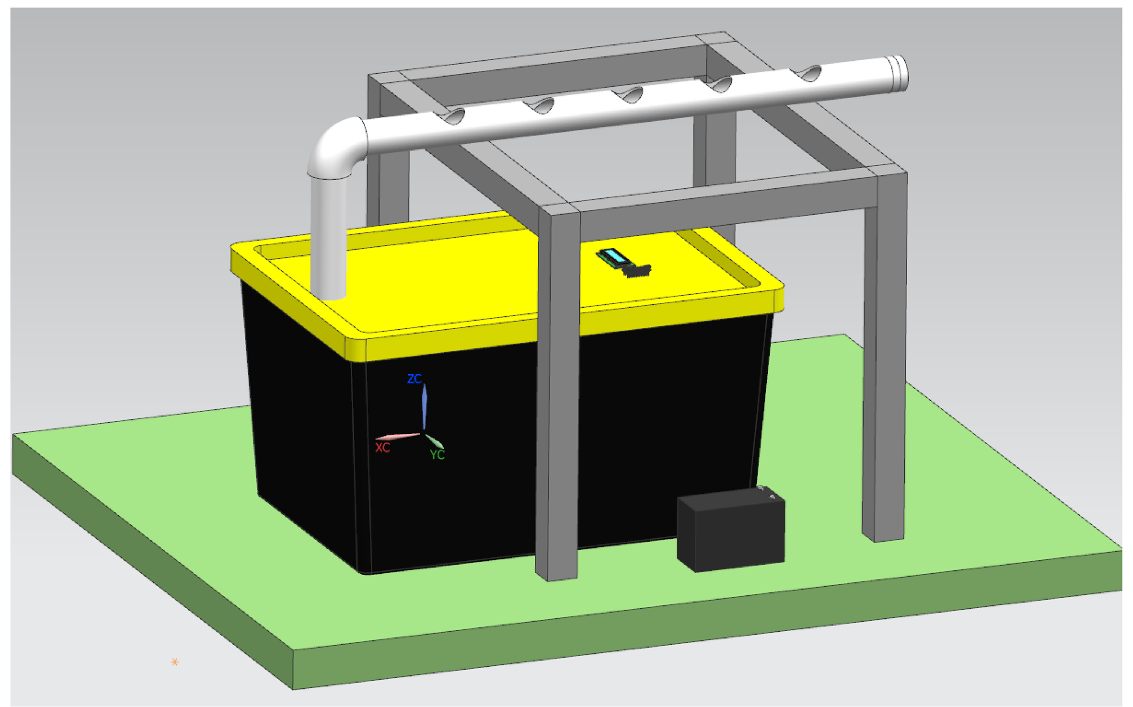

Figure 2: Hydroponic System Design

Results and Discussion

The system works according to the design. The system runs great with the power supply adapter. It powers the water and oxygen pumps, the Arduino with its sensors and the LCD screen. The system was expected to run for at least 9-16 hours with the battery since the systems circuit with the materials would require 1.3 Amps and the power output is of 8.98W. The system ran for at least 20 hours. The voltage from the battery was measured each hour for 11 hours, then it was left running until it stopped with a battery voltage of 4.96V.

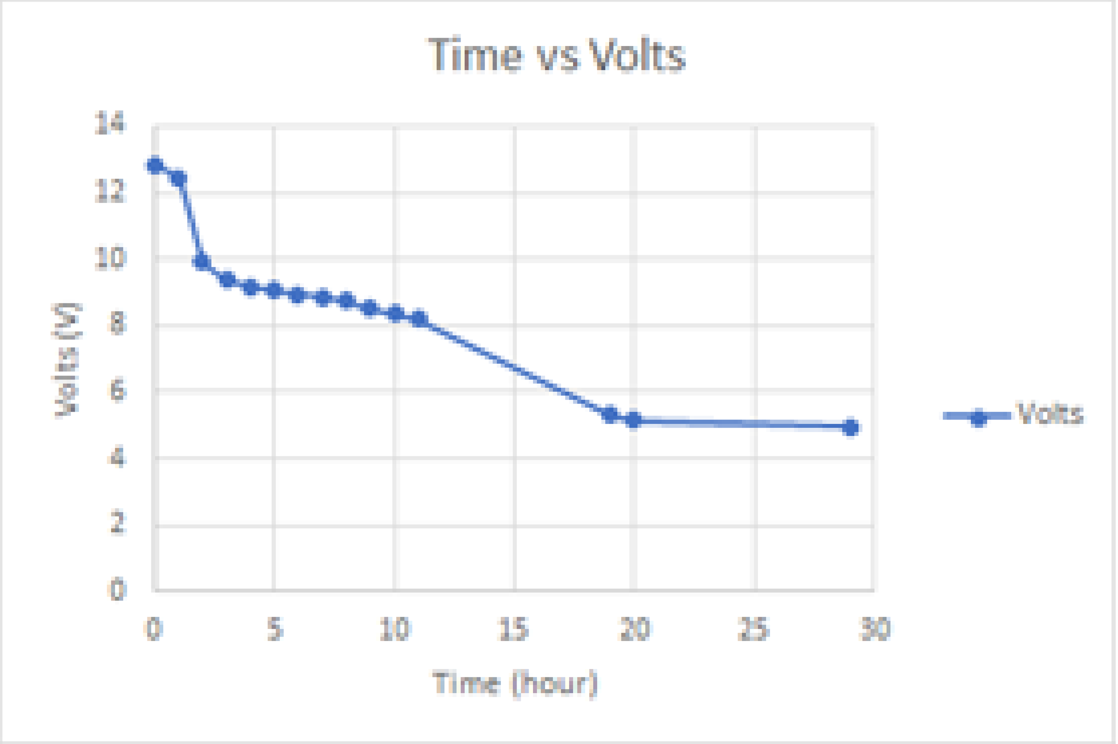

Figure 3: Battery Voltage Graph

Values of the probe sensor used for the Arduino was compared with a complete pH and temperature sensor and they gave different results. The pH level was of 6.56 at the start. This value is favored since it is close to the recommended pH value between 5.6 and 6.2. The Arduino's pH probe gave a pH value of 3.5. The procedure of calibrating this probe is complex since its data sheet does not give clear instructions. An attempt of calibrating it again was made but it gave far worse results. After having the system running for 1 week, the pH level was of 6.15 and the nutrient volume in the tote was of 6.75 gallons with the system running with a flow rate of 3.5L/min. The 0.41 difference in pH level shows that the lettuce is absorbing the nutrients from the solution while the volume of the solution in the tote, starting from 15 gallons, reduced to 6.75 gallons due to the lettuce absorbing the solution but mostly from evaporation since the lid is not completely closed. The water level sensor provided information to the Arduino and the LCD screen showed that the nutrient level in the tote was low.

Figure 4: Lettuce in the Hydroponic System

Applying a closely recommended flow rate of 0.24L/min [3] produced better results. The lettuce showed a faster growth rate since it absorbs the nutrients more effectively. This is because the nutrient solution at a lower flow rate lets the lettuce obtain oxygen without being completely dry.

Conclusions

The system implemented runs according to the design. This system ran for an outstanding 20 hours, which gives the owner of the hydroponic plenty of time to find another way to sustain their plants. The Arduino pH probe used was not of use since the calibration procedure is confusing and does not give correct results. The water quality meter sensor was easier to calibrate and gave favorable results. It is not part of the circuit design, and it is not used with Arduino, but it gives the correct pH value and it's powered by batteries, The water level sensor was easy to install and to program, it is recommended for this kind of system. The system designed for testing was not adequate since the flow rate was much bigger than needed. A solution to this is to use a bigger hydroponic where the flow rate is divided to different pipes. That way the hydroponic can harvest much more quantities of lettuce. The system designed is self-sufficient and runs efficiently. It also shows the nutrient solution level of the tote and less human interaction is needed. This system designed will help people with their hydroponics and plants in case of future power outages occurring for a long period of time.

Future Work

- Adapt the design to a bigger system
- Provide this design to farmers in Puerto Rico
- Improve this design with other sensors
- Implement internet communication with the owner of the system

Acknowledgements

Special thanks to:

- Prof. Julio Noriega
- My parents Sonia De Jesús and Cosme Santos
- OASIS Synergistic Technologies
- All Ponics
- Dra. Denisse M. Cobián

References

1. E. D. Schafer, "Hydroponics," Salem, 2012. [Online]. Available: online.salempress.com. [Accessed: 18 April 18, 2022].
2. Eunice, "Grower Today," 2022. [Online]. Available: https://www.growertoday.com/ph-for-hydroponic-lettuce/. [Accessed: May 4, 2022].
3. A. Razzaq Al-Tawaha, G. Al-Karaki, A. Rahman Al-Tawaha, S. Nurani Sirajuddin, I. Makhadmeh, P. E. Megat Wahab, R. A. Youssef, W. Al Sultan, and A. Massadeh, "Effect of water flow rate on quantity of lettuce (Lactuca sativa L.) in nutrient film technique (NFT) under hydroponics conditions," *Bulgarian Journal of Agricultural Science*, vol. 24, no. 5, pp. 793-800, 2018.