Design of reservoir tanks modelling to mix several types of fertilizer for fertigation planting system: part b

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Abstract. Fertigation is a process that combines fertilization and irrigation by injecting soil amendments, fertilizers, and other water-soluble products into an irrigation system. In order to achieve the higher productivity and maintaining environmental quality in agriculture, water and nutrients are the two most critical inputs. The importance of fertigation system is to control the salinity and pH value of fertilizer solution. In Malaysia, manual method is used in order to mix the fertilizer solution and manually takes the reading of EC and pH of the solution. This research is to develop a fertigation system that can mix several types of fertilizer and to design a system that can mix the concentration and pH value of fertilizer using Arduino system and PID controller. Electrical conductivity and pH sensor will be immersed in the main tank and start to give a feedback. When the controller detects an error, it will do a correction to the system. In this research, several conditions of PID parameter were used to conduct the experiment. Different parameters of PID would give different result and settling time. The best settling time was when the experiment was conducted using PID parameter of $K_p = 50$, $K_i = 150$, $K_d = 3$ which took 130s to mix the fertilizer solution. When the experiment was conducted using $K_p = 50$, $K_i = 10$, $K_d = 3$, the settling became longer which took 250s to recover the desired salinity and pH range of value. From the finding result, it proves that this system can control and give feedback to the change of salinity and pH value.

1. INTRODUCTION

In agricultural industries, crops need water to grow healthily. Three quarters of the earth surfaces are covered with water which includes the rivers, seas and lakes. The sources of irrigation for the largest area only depend on rainfalls. In Malaysia, especially, there are 3000mm rainfalls for 200 days per year and it allows the variation of crops to grow[1]. Irrigation and fertigation are important in the agricultural industry as with these methods, the farmer can control the plants’ growth, quality, and fruit yield. The introduction of this system is able to help farmers to optimally control these two methods. In fertigation system, the two types of soluble fertilizers are dissolved in water and will be supplied to the crops through the irrigation line by using the injection pump[2]. It is a method of farming whereby complete manure is given to the vegetation in the form of solution which is channelled to the root zone through a drip irrigation system. In order to achieve higher productivity and maintaining environmental quality in agriculture, water and nutrients are the two most critical inputs. Applying plant nutrients by dissolving them in irrigation water using drip system can be the most efficient way of nutrient application. Insufficient and excessive amounts of water and mixing fertilizer can lead to unhealthy plant growth and can cause the plant to wilt.
It is important to control the concentration and pH value of fertilizer in fertigation planting system. The fertilizer that will drip to the planting system gives an important aspect in plant growth. In Malaysia, manual method was used to prepare the fertilizers as the farmer will pour the crystal fertilizer into a tank containing water and stir it manually before put into the main tank[3]. There are two types of fertilizer to be stirred in different tanks and this will take time and huge labour. After that, the farmer needs to take the reading of the fertilizer concentration and pH value to maintain the quality of the plant. A system will be developed to control and maintain the concentration and level of pH in fertilizer by using electronic conductivity (EC) sensor, pH sensor and Arduino system and it will be implemented on three tanks reservoirs.

2. METHODOLOGY
In order for fertigation system to be successfully functioning, the system must be able to run a few important tasks automatically. The tasks include controlling nutrients needed by the crops, analysing the condition of the environment, mixing nutrients in the solution tank and pumping them into an irrigation line. Automatic fertigation system will involve software and hardware implementation. The main microcontroller used in this system is Arduino Uno. The sensor is also important to control the salinity and pH value to mix the fertilizer solution. Two types of sensor used in this research were electrical conductivity and pH sensor.

2.1 DESIGN CONCEPT

| Concept 1 | Concept 2 | Concept 3 |
|---|---|---|
| ![Diagram](image1.png) | ![Diagram](image2.png) | ![Diagram](image3.png) |

Table 1. Concept design
Pugh chart is a particularly helpful alternative for determining the most effective design concepts among the alternatives generated. The comparison between each concept to a datum or benchmark concept and for each criterion listed whether the concept in question is better than, poorer than or the same as the benchmark concept[4]. From the total score obtained, it shows concept 3 is the best system to be implemented in this research. The installation of the system is easier compared to the benchmark system which is more complex. Even though the maintenance of this concept is not as good as other concept, but the time for the farmer to mix the fertilizer is faster and easy.

2.2 LIST OF COMPONENTS
From the selected concept design, several components were listed to be implemented in the system. The list of the component is as shown in Table 2.

| No. | Component Name                            | Component Diagram          |
|-----|-------------------------------------------|-----------------------------|
| 1.  | Controller Box                            |                             |
| 2.  | Electrical Conductivity And pH Sensor     |                             |
| 3.  | Temperature Sensor                        |                             |
| 4.  | 220V Aquarium Water Pump                  |                             |
| 5.  | 12V Mini Water Pump                       |                             |
Arduino Uno is a microcontroller circuit board that has a chip on it that can be programmed to do many different things. Arduino consists of simple hardware and easy to use without being an expert programmer. Just with one click, a free source code can be compiled or uploaded in the system. Arduino is likewise the most mainstream microcontroller board that has been used by beginner or advanced users. This microcontroller has been used to make automotive project, robotic, home automation gadgets, lock and servos, sound and video, for sensing or controlling light, and the most important is it can be used as a system for sensing pH and electronic conductivity in solution. Using the closed loop system, the value of electric conductivity and pH are analysed by the controller to ensure the mixing fertilizer is within the desired range.

The pH reading in fertigation system was measured by pH electrode. mili-volts (mV) is the output signal of pH electrode. There is a ball at the end of the pH electrode with specific surface properties able of ion exchange. The pH in irrigation water is very important because it may affect the chemical reaction. The working principle of pH electrode depends on the rule that a potential is created when two arrangements of various pH come in contact through a thin glass film. The pH value of a solution will indicate how alkaline or acidic it is. Measurement loop of a pH is made of several components – a reference electrode, measuring electrode, temperature sensor and transmitter, or analyser.

Liquid is essential in our daily lives. It may include water, daily product, chemical, pharmaceutical product, and many more. The quality of liquid is determined by the chemical and physical properties [5]. To access these properties, various principles of measurement are used. One of the principles is the measurement of electrical conductivity in the solution. The electrical conductivity arises from the dissociation of soluble salt, bases, and acid to form positively charged cation and negatively charged anion. This ion contributes to the change transport in the electrical field.

Conductivity also depends on the medium temperature. Therefore, the temperature is measured in parallel and conductivity value refers to a reference temperature of 25°C of the transmitter. The inductive measuring principle uses the inductor conductivity sensor. It contains electromagnetic transmission and reception coil in protective plastic coating. An alternating magnetic field is generated in transmission coil which induces electric voltage in liquid. This will cause positively and negatively charged ions of the liquid to move and generate an alternating current. The intensity of the current depends on the number of free ions in a medium. It is evaluated by the transmitter, and conductivity is calculated.

12V of water pump was used to supply the nutrient types A and B into the main tank. The slow flow rate of water pump is needed because once fertilizer A and B was pumped into the main tank, high power of 220V aquarium pump would circulate the water in order to well mix the fertilizer. The sensor takes time to analyse the feedback because the main tank is large. If the flow rate is too fast, overflow of nutrient will happen before the sensor gives feedback to the controller.
To store the well-mixed fertilizer solution and two types of fertilizer A and B, 3 tanks were used in this research. The size of the main tank used in this system was 550-liter water reservoir tank. This tank is made from strong durable blow moulded high-density polyethylene. Non-hazardous material is suitable for this tank.

The crystal fertilizer will dissolve with water before mixed in the main tank. Two 120-liter capacity tanks were used to contain fertilizer A and B. This tank is also made of high-density polyethylene material. This tank has a secure fitting clamp lid. It is suitable for chemical or pharmaceutical with good resistant to most substances.

2.3 SYSTEM IMPLEMENTATION
The actual design of this project is as shown in Figure 1. The nutrients were stored in tanks A and B. The controller controls the amount of nutrient to be supplied into the main tank. A hose from the main and fertilizer tank was connected to the 12V pump at the controller while 220V aquarium pump was used to circulate the water. Three sensors which are EC, pH, and temperature sensor, were also connected to controller box and the sensor was immersed in the main tank. 9V power supply was used to operate this system.

Once the controller received the predetermined value of EC and pH, the 12V pump stopped running which meant to stop the nutrient from supplied into the main tank. The range value of EC is needed to mix the fertilizer solution is between 1.8-1.9 ms/cm. If the nutrient pump pumps more than the value that the system needs, a pump will turn on and pump the water to the main tank in order to achieve the stable value.

3. RESULT AND DISCUSSION
In this research, several conditions of PID parameter were used to conduct the experiment in order to mix the fertilizer solution. The first experiment was where $K_P$ value was varied while the $K_I$ and $K_D$ values were constant. For the second experiment, $K_P$ value was used as the shortest settling time from the first experiment and $K_D$ value was set as a constant while $K_I$ was a variable. In the last experiment, the $K_P$ value was taken from the shortest settling time from experiment 1 and $K_D$ value was taken from the shortest settling time from the second experiment. The $K_D$ value became the variable. Each experiment had five sets of data and the total sets of data were 15. The detailed parameter of the experiment is as shown in Table 3.

| Parameter | $K_P$ parameter | $K_I$ parameter | $K_D$ parameter |
|-----------|----------------|----------------|----------------|

Figure 1. Actual fertigation system
| Experiment  | 1.1  | 1.2  | 1.3  | 1.4  | 1.5  | 2.1  | 2.2  | 2.3  | 2.4  | 2.5  | 3.1  | 3.2  | 3.3  | 3.4  | 3.5  |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1.1        | 10   |      |      |      |      | 50   |      |      |      |      |      |      |      |      |      |
| 1.2        |      | 20   |      |      |      |      | 50   |      |      |      |      |      |      |      |      |
| 1.3        |      |      | 30   |      |      |      |      | 50   |      |      |      |      |      |      |      |
| 1.4        |      |      |      | 50   |      |      |      |      | 50   |      |      |      |      |      |      |
| 1.5        |      |      |      |      | 100  |      |      |      |      | 50   |      |      |      |      |      |
| 2.1        |      |      |      |      |      | 50   |      |      |      |      | 50   |      |      |      |      |
| 2.2        |      |      |      |      |      |      | 50   |      |      |      |      | 50   |      |      |      |
| 2.3        |      |      |      |      |      |      |      | 50   |      |      |      |      | 50   |      |      |
| 2.4        |      |      |      |      |      |      |      |      | 50   |      |      |      |      | 50   |      |
| 2.5        |      |      |      |      |      |      |      |      |      | 50   |      |      |      |      | 50   |
| 3.1        |      |      |      |      |      |      |      |      |      |      | 50   |      |      |      |      |
| 3.2        |      |      |      |      |      |      |      |      |      |      |      | 50   |      |      |      |
| 3.3        |      |      |      |      |      |      |      |      |      |      |      |      | 50   |      |      |
| 3.4        |      |      |      |      |      |      |      |      |      |      |      |      |      | 50   |      |
| 3.5        |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 50   |

Based on the system analysis feedback, all the experiments conducted were in a positive feedback. For experiment 1, there were five sets of data in which the $K_P$ parameter was set as variable. Five different parameters of $K_P$ were used which were 10, 20, 30, 50, and 100. Only the best three results were discussed in this topic and the plotted graph of EC against time as shown in Figure 2. When the parameter of $K_P$ was set as 20, the total settling time to achieve the desired range of value was 180s. When the value of $K_P$ increased to 30, the settling time became 160s and reduced to 140s when $K_P$ was set at 50. The percentage of overshoot was the highest when $K_P$ was set at 20 which was 27.9% and for $K_P$ set at 50 the overshoot percentage was 17.4%. For experiment using $K_P$ as 30, no overshoot occurred. For pH comparison, the graph is as shown in Figure 3 and no overshoot occurs.
From experiment 2, the $K_I$ parameters were set as the variable. The best three results were as shown in Figure 4 when the $K_I$ values were set as 150, 200, and 250. The settling time of these three experiments were 130s, 150s, and 170s, respectively. Overshoot only occurred when $K_I$ was set as 250 which the percentage of 7.7%. pH graph illustration is as shown in Figure 5.
From experiment 3, the three shortest settling time for the system to recover the value of EC and pH was when the experiment was done by using the PID condition of $K_D$ set as 1, 2 and 4. When the $K_D$ parameter was set as 1, the time to recover the value was at 170s and increased to 190s when the value changed to 2. However the settling time became faster when the parameter was set as 4 which took 160s to mix the fertilizer solution. The percent of overshoot was 34.8% when the $K_D$ was set as 1 and 7.1% when the $K_D$ was set as 4. The comparison graph of EC and pH can be seen in Figures 6 and 7.

Referring to Figures 8 and 9, it can be seen the best three settling time to mix the fertilizer solution among all the three conditions of the experiment and experiment without using PID. Table 4 shows the detail of the best three experiments and experiment without using PID.

| Experiment | $K_p$ | $K_i$ | $K_d$ | Settling Time | Overshoot percentage |
|------------|-------|-------|-------|---------------|----------------------|
| 5.6        | 5.8   | 6.0   | 6.2   | 6.4           | 6.6                  |
| 7.0        | 7.2   | 7.4   | 7.6   | 7.8           | 8.0                  |
| 5.0        | 5.2   | 5.4   | 5.6   | 5.8           | 6.0                  |

Table 4. Detail of the best three experiments
From the data obtained, the best settling time is when the condition of PID was $K_P = 50$, $K_I = 150$, $K_D = 3$ which took 130s. The second best time to recover the level of EC and pH was 140s when the PID condition was $K_P = 50$, $K_I = 100$, $K_D = 3$ followed by the condition of $K_P = 50$, $K_I = 150$, $K_D = 4$ at 160s. While that, the experiment conducted without using PID took 190s to achieve the desired value.

| Experiment | $K_P$ | $K_I$ | $K_D$ | Time (s) | EC (%)  |
|------------|-------|------|-------|----------|---------|
| 1.3        | 50    | 100  | 3     | 140s     | 17.4%, 2.2% |
| 2.3        | 50    | 150  | 3     | 130s     | -       |
| 3.3        | 50    | 150  | 4     | 160s     | 7.1%    |
| Experiment without PID | -     | -    | -     | 190s     | 6.5%, 7.6%, 10.9% |

Figure 8. Graph of best three comparison PID Condition of EC Value (ms/cm) against Time (s)

Figure 9. Graph of best three comparison PID Condition of pH against Time (s)

While conducting this research, some difficulties were faced such as lack of knowledge about the coding of Arduino controller. The time taken to finish constructing the coding took a very long time including the trial and error process. Sometimes the coding made was unsuccessful and needed to change according to the flow of the coding. Eventually, with the help of lecturers and friends, the Arduino programming coding was successfully completed. Problems also occurred in the pump motor used to pump the fertilizer into the main tank. After connecting all the electrical components and sensors on the controller was completed, the pump motor cannot function properly. After identifying the problem, the pump motor has to be replaced.

The sensors also needed to be calibrated because sometimes the sensors show inaccurate reading and the reading is also not stable. This will usually happen when using the lab probe sensor. Financial limitation forced this research to use lab probe instead of industrial sensor.
4. CONCLUSION
This project was about designing a system that can control and maintain EC and pH value of fertilizer in fertigation planting system. By applying the automation system, it can ease the farmer to prepare the fertilizer solution before supplying it to their crop. The mixing of fertilizer was also more accurate and efficient.

Based on the analysis and data obtained from the previous chapter, it can be seen from several findings with different PID conditions. By referring to Figures 14 and 15, it shows the best three among all the experiments. The time to mix the fertilizer solution in the main tank only took 130s to achieve the range value of EC and pH by using the PID conditions of $K_p = 50$, $K_i = 150$ and $K_d = 3$. During this research, I have made some visits to the chili plantations using fertigation system. From the visits, normally, the farmer took 4 to 5 minutes to mix the fertilizer solution. By using this automatic system, it clearly showed that we can reduce the time and also the farmer’s energy.

In conclusion, all the objectives of this research were achieved. This system is able to mix several types of fertilizer, fertilizer A and B. Using Arduino Uno as a controller, the mixing of fertilizer was easier and faster and didn’t need a lot of human energy compared to the old system. All the coding was set at the controller and the sensor was connected to the controller as shown in Figure 3.8. When the sensor detected that the value was out of range, the controller sent feedback for water pump to pump Fertilizer A and B into the main tank and stopped until the sensor achieved the desired range of EC ad pH value. In order to get more accurate results, PID controller was used in this system. Different conditions of PID parameter will give different results and settling time. It is proved that the controller and sensor used in this system can control and maintain the salinity and pH of fertilizer solution and this system can be applied in fertigation planting system.

5. REFERENCES
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