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Smart Fertigation Control System of Plantation Chili in Greenhouse

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Smart Fertigation System, Plantation Chili (Capsicum Annum), Bang Bang controller, PID controller

Abstract

The Smart Fertigation Control System has gained significant attention in greenhouses due to its potential to enhance crop management and ensure agricultural sustainability in chili (Capsicum annuum) plantations. This study aimed to develop a smart fertigation system for chili plantations, investigate suitable control schemes, and evaluate the effectiveness of these schemes compared to traditional methods. An experimental approach was employed to compare two types of controllers, Bang-bang and PID, for delivering two different types of fertilizer into a mixing tank. The experiment, conducted using Arduino IDE software, applied the formulations of these controllers to achieve sustainable fertilizer delivery. Results indicate that the PID controller is more effective and sustainable in controlling the system compared to the Bang-bang controller. The primary variable in this study was the pH setpoint, with the goal of mixing two fertilizers with low and high pH to achieve a pH of 7.5. Maintaining a constant pH value as shown on the serial monitor was essential throughout the research. The findings suggest that the PID controller significantly improves the growth and sustainability of chili plants compared to traditional fertigation methods.

1. Introduction

Chili cultivation is vital to Malaysia's economic system and delicacies, but traditional farming techniques conflict with demanding situations such as unpredictable climate and coffee yields. To cope with those issues, integrating fertigation, which mixes fertilization and irrigation, with advanced greenhouse era offers a promising answer with the aid of optimizing nutrient shipping and offering a managed surroundings for plants. Despite the evolution of these techniques, there may be an opening in understanding the overall performance of clever fertigation structures using numerous controllers (e.G., P, PI, PD, PID, bang-bang). This task pursuits to increase and evaluate a smart fertigation gadget to beautify precision and efficiency in nutrient transport, leveraging IoT technology, sensors, and automation to revolutionize greenhouse farming practices. By doing so, it seeks to growth productivity, lessen useful resource use, and meet international agricultural requirements, in the long run contributing to sustainable and efficient chili cultivation in Malaysia.

This bankruptcy outlines the improvement of an advanced smart fertigation device aimed toward precision agriculture, making use of superior technologies such as IoT and AI. The gadget integrates key additives like sensors, actuators, and a RaspberryPi microcontroller to efficiently mixing the fertiliser thru a drip fertigation device. Key components encompass ultrasonic, EC, and pH sensors, in conjunction with pumps and a Raspberry

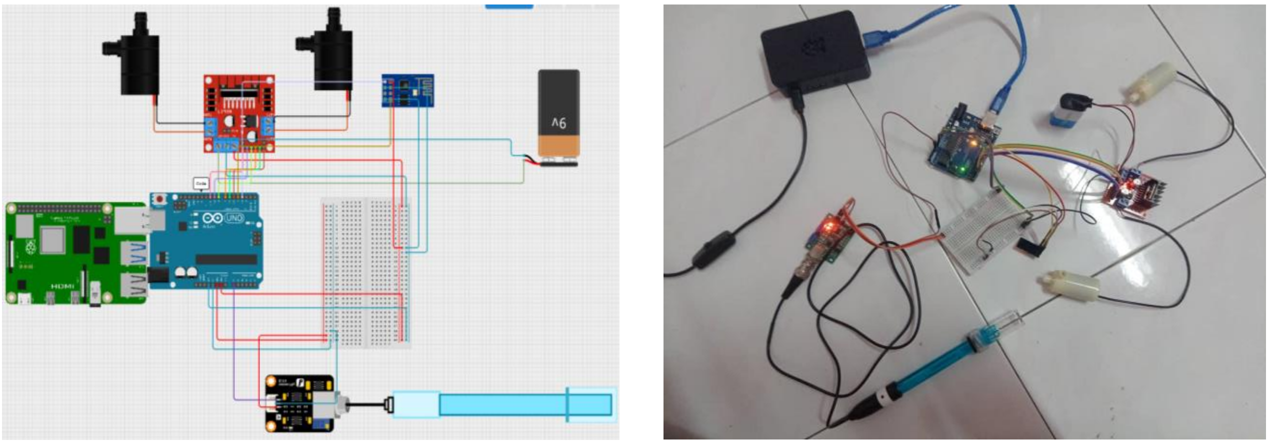
Pi controller that employs Fuzzy and PID manage strategies to make certain most efficient nutrient shipping. The structure, analogous to the OSI version, includes layers for sensing, data transmission, processing, and consumer interface, making sure real-time monitoring and facts-driven decision-making [1-8].

The system's layout and implementation cope with demanding situations of conventional farming by using leveraging advanced controllers, which includes PID and hybrid fuzzy-PID controllers, to enhance precision and efficiency [9-12]. Control strategies, including a Mamdani-kind fuzzy controller and a Bang-Bang controller, are explored, highlighting their roles in retaining most desirable nutrient awareness and pH ranges [13-14]. Advantages of clever fertigation consist of expanded performance, resource conservation, and reduced labor costs through automation [16-19]. However, demanding situations which include high initial setup costs, technical complexity, facts management, and connectivity troubles are recounted [17].

The bankruptcy also delves into the utility of this machine in chili (Capsicum annuum) cultivation, emphasizing its ability to transform agricultural practices [20]. It examines pink chili plantation in the context of post-catastrophe healing in Aceh Province, Indonesia, wherein progressed agricultural technology had been important for economic revival [20]. Despite demanding situations like plant disturbances, drought, and limited farmer talents, red chili farming stays a viable monetary pastime with sizeable social impact, specifically in struggle-affected communities [21-23]. This complete exploration underscores the importance of integrating clever fertigation systems in cutting-edge agriculture to decorate sustainability, productiveness, and financial resilience.

2. Design and Implementation

2.1 Architecture

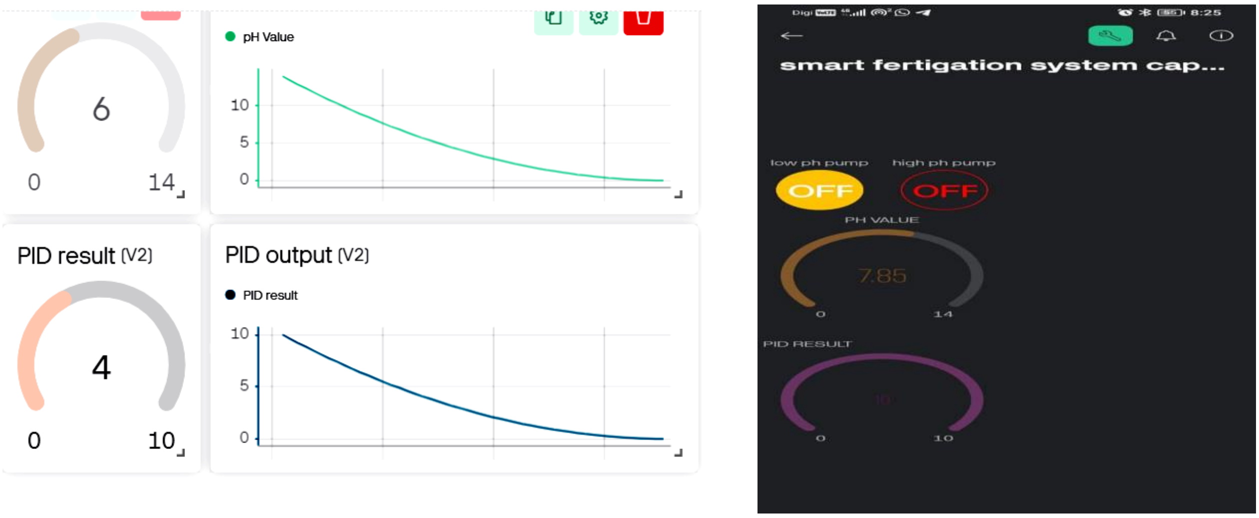


(a) **(b)**

Fig. 1 *Architecture (a) The initial sketching of the hardware; (b) The real world design of hardware*

Figure 1 indicates the schematic connection of the device hardware. The machine consists of a pH sensor as the main input, used to evaluate the overall performance of Bang-Bang and PID controllers in handling one of a kind pumps linked to an L298N DC motor driving force with a 9V battery. These pumps—low pH and high pH to hold the fertilizer in mixing tank's pH on the desired pH value of 7.5. The pH sensor and motor driving force are connected to an Arduino Uno, that's used for sensor configuration and calibration. The Arduino Uno is linked to a Raspberry Pi 4B and an ESP-01 module, allowing data logging and adding IoT capability. All hardware components are powered through a laptop that connected to the Raspberry Pi 4B.

2.2 Software Design



(a) **(b)**

Fig. 2 *Software (a) Blynk console dashboard design; (b) Blynk application from mobile*

The application design is based on the configuration available on the Blynk Console dashboard application. The widget used to display the data chosen to show the trend and timeline of the data recorded. This accomplished with the graph widget for each of the four parameters. This is help to ensure whether the previous data stable or exhibit. The gauge that using is to recognize the current value of the pH sensor above or within the standard threshold. Once configured, mobile phone also can be download the blynk application and continue remote through the mobile phone by login the same account and same password.

2.3 Implementation

The implementation info the setup and execution of an test to compare Bang Bang and PID controllers in maintaining the pH stages of a fertilizer mixing tank. By utilizing Arduino for sensor statistic processing and control and Raspberry pi 4B with Blynk for IoT functionality and statistics logging, we make sure a complete method to tracking and adjusting the pH desired value. This setup not only highlights the variations in control strategies however also presents insights into practical application in computerized agriculture structures.

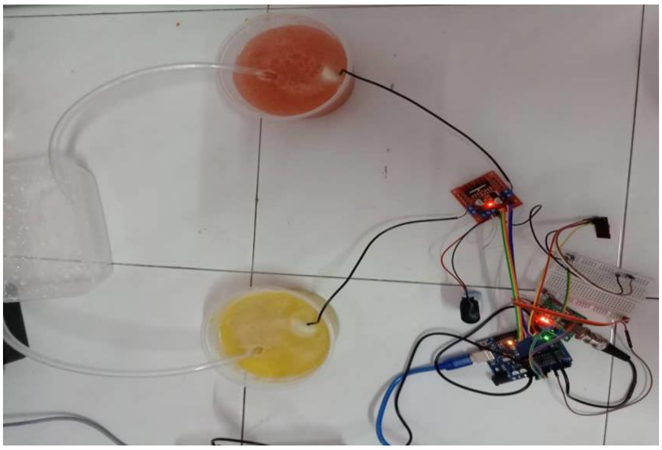


Fig. 3 *The simulation of fertigation system*

3. Result and Discussion

From the experiments, the comparison of bang bang and PID controller whether in keeping pH value in a chili plantation well known shows wonderful variations of their performance and control strategies. The below shows the Table 1 and Table 2 for the bang bang and PID controller respectively in the real time recorded experiment.

Table 1 *The real time result for Bang Bang controller used*

Time/s	pH value	high pH pump	low pH pump
0:02	9.54	1	0
0:04	9.51	1	0
0:06	9.48	1	0
0:08	8.9	1	0
0:10	8.87	1	0
0:12	8.84	1	0
0:14	8.81	1	0
0:16	8.79	1	0
0:18	8.76	1	0
0:20	8.73	1	0
0:22	8.7	1	0
0:24	8.67	1	0
0:26	8.64	1	0
0:28	8.61	1	0
0:30	8.58	1	0
0:32	8.55	1	0
0:34	8.53	1	0
0:36	8.5	1	0
0:38	8.47	1	0
0:40	8.44	1	0
0:42	8.41	1	0
0:44	8.38	1	0
0:46	8.35	1	0
0:48	8.32	1	0
0:50	8.29	1	0
0:52	8.26	1	0
0:54	8.24	1	0
0:56	8.21	1	0
0:58	8.18	1	0
1:00	8.15	1	0
1:02	8.12	1	0
1:04	8.09	1	0
1:06	8.06	1	0
1:08	8.03	1	0
1:10	8	1	0
1:12	7.98	1	0
1:14	7.95	1	0
1:16	7.92	1	0
1:18	7.89	1	0
1:20	7.86	1	0
1:22	7.83	1	0
1:24	7.8	1	0
1:26	7.77	1	0
1:28	7.74	1	0
1:30	7.72	1	0
1:32	7.69	1	0
1:34	7.66	1	0
1:36	7.63	1	0
1:38	7.6	1	0
1:40	7.57	1	0
1:42	7.54	1	0
1:44	7.32	0	1
1:46	6.89	0	1

Table 2 *The real time result for the PID controller used*

Time	pH	pid Output
0:02	9.54	0.57
0:04	9.51	1.23
0:06	9.48	4.45
0:08	8.9	1.56
0:10	8.87	1.65
0:12	8.84	1.64
0:14	8.81	1.63
0:16	8.79	1.62
0:18	8.76	1.61
0:20	8.73	1.6
0:22	8.7	1.59
0:24	8.67	1.58
0:26	8.64	1.57
0:28	8.61	1.56
0:30	8.58	1.55
0:32	8.55	1.53
0:34	8.53	1.52
0:36	8.5	1.51
0:38	8.47	1.5
0:40	8.44	1.49
0:42	8.41	1.48
0:44	8.38	1.47
0:46	8.35	1.46
0:48	8.32	1.45
0:50	8.29	1.44
0:52	8.26	1.43
0:54	8.24	1.42
0:56	8.21	1.41
0:58	8.18	1.4
1:00	8.15	1.38
1:02	8.12	1.37
1:04	8.09	1.36
1:06	8.06	1.35
1:08	8.03	1.34
1:10	8	1.33
1:12	7.98	1.32
1:14	7.95	1.31
1:16	7.92	1.3
1:18	7.89	1.29
1:20	7.86	0.457
1:22	7.83	1.27
1:24	7.8	1.26
1:26	7.77	1.25
1:28	7.74	1.24
1:30	7.72	0.24
1:32	7.69	1.21
1:34	7.66	1.2
1:36	7.63	1.19
1:38	7.6	1.18
1:40	7.57	0.77
1:42	7.54	1.16
1:44	7.51	1.15
1:46	7.48	1.14
1:48	7.46	1.13
1:50	7.43	0.98
1:52	7.4	1.11

1:48	7.09	0	1
1:50	7.2	0	1
1:52	7.4	0	1
1:54	7.6	1	0
1:56	7.45	0	1
1:58	7.48	0	1
2:00	7.54	1	0
2:02	7.6	1	0
2:04	7.66	1	0
2:06	7.37	0	1
2:08	7.32	0	1
2:10	6.89	0	1
2:12	7.09	0	1
2:14	7.2	0	1
2:16	7.4	0	1
2:18	7.6	1	0
2:20	7.45	0	1
2:22	7.48	0	1
2:24	7.54	1	0
2:26	7.6	1	0
2:28	7.66	1	0
2:30	7.4	0	1
2:32	7.37	0	1
2:34	7.43	0	1
2:36	7.48	0	1
2:38	7.54	1	0
2:40	7.6	1	0
2:42	7.66	1	0
2:44	7.62	1	0
2:46	7.59	1	0
2:48	7.56	1	0
2:50	7.52	1	0
2:52	7.49	0	1
2:54	7.46	0	1
2:56	7.42	0	1
2:58	7.39	0	1
3:00	7.46	0	1
3:02	7.52	1	0
3:04	7.59	1	0
3:06	7.54	1	0
3:08	7.6	1	0
3:10	7.66	1	0
3:12	7.62	1	0
3:14	7.59	1	0
3:16	7.56	1	0
3:18	7.52	1	0
3:20	7.49	0	1
3:22	7.46	0	1
3:24	7.42	0	1
3:26	7.39	0	1
3:28	7.46	0	1
3:30	7.52	1	0
3:32	7.59	1	0
3:34	7.54	1	0
3:36	7.6	1	0
3:38	7.66	1	0
3:40	7.62	1	0
3:42	7.59	1	0
3:44	7.56	1	0
3:46	7.52	1	0

1:54	7.37	1.1
1:56	7.43	1.12
1:58	7.48	0.68
2:00	7.54	1.18
2:02	7.6	1.21
2:04	7.66	1.24
2:06	7.62	1.12
2:08	7.59	1.11
2:10	7.56	1.1
2:12	7.52	1.12
2:14	7.49	0.43
2:16	7.46	1.12
2:18	7.42	0.57
2:20	7.39	1.1
2:22	7.46	1.12
2:24	7.52	1.15
2:26	7.59	0.34
2:28	7.43	0.45
2:30	7.4	0.87
2:32	7.37	0.23
2:34	7.43	0.13
2:36	7.48	0.31
2:38	7.54	0.88
2:40	7.6	0.87
2:42	7.66	0.45
2:44	7.62	0.87
2:46	7.59	0.23
2:48	7.56	0.13
2:50	7.52	0.31
2:52	7.49	0.88
2:54	7.46	0
2:56	7.42	1
2:58	7.39	0.45
3:00	7.46	0.87
3:02	7.52	0.23
3:04	7.59	0.13
3:06	7.56	0.31
3:08	7.56	0.88
3:10	7.55	0.2
3:12	7.58	0
3:14	7.56	0.45
3:16	7.55	0.87
3:18	7.56	0.23
3:20	7.55	0.13
3:22	7.58	0.31
3:24	7.56	0.88
3:26	7.55	0
3:28	7.46	0
3:30	7.52	0.45
3:32	7.59	0.87
3:34	7.56	0.23
3:36	7.56	0.13
3:38	7.55	0.31
3:40	7.58	0.88
3:42	7.56	0
3:44	7.46	0
3:46	7.52	0.07
3:48	7.59	0
3:50	7.56	0
3:52	7.56	0

3:48	7.49	0	1
3:50	7.46	0	1
3:52	7.42	0	1
3:54	7.39	0	1
3:56	7.46	0	1
3:58	7.52	1	0
4:00	7.59	1	0
4:02	7.54	1	0
4:04	7.6	1	0
4:06	7.66	1	0
4:08	7.62	1	0
4:10	7.59	1	0
4:12	7.56	1	0
4:14	7.52	1	0
4:16	7.49	0	1
4:18	7.46	0	1
4:20	7.42	0	1
4:22	7.39	0	1
4:24	7.46	0	1
4:26	7.52	1	0
4:28	7.59	1	0
4:30	7.54	1	0
4:32	7.6	1	0
4:34	7.66	1	0
4:36	7.62	1	0
4:38	7.59	1	0
4:40	7.56	1	0
4:42	7.52	1	0
4:44	7.49	0	1
4:46	7.46	0	1
4:48	7.42	0	1
4:50	7.39	0	1
4:52	7.46	0	1
4:54	7.52	1	0
4:56	7.59	1	0
4:58	7.54	1	0
5:00	7.6	1	0
5:02	7.66	1	0
5:04	7.62	1	0
5:06	7.59	1	0
5:08	7.56	1	0
5:10	7.52	1	0
5:12	7.49	0	1
5:14	7.46	0	1
5:16	7.42	0	1
5:18	7.39	0	1
5:20	7.46	0	1
5:22	7.52	1	0
5:24	7.59	1	0
5:26	7.54	1	0
5:28	7.6	1	0
5:30	7.66	1	0
5:32	7.62	1	0
5:34	7.59	1	0
5:36	7.56	1	0
5:38	7.52	1	0
5:40	7.49	0	1
5:42	7.46	0	1
5:44	7.42	0	1
5:46	7.39	0	1

3:54	7.55	0.02
3:56	7.46	0
3:58	7.52	1.6
4:00	7.59	0.14
4:02	7.56	0
4:04	7.56	0
4:06	7.55	0.5
4:08	7.58	0.3
4:10	7.46	0.4
4:12	7.52	0
4:14	7.59	0
4:16	7.56	0.04
4:18	7.56	0.1
4:20	7.55	0
4:22	7.58	0.24
4:24	7.56	0
4:26	7.55	0
4:28	7.56	0.2
4:30	7.62	0
4:32	7.56	0.48
4:34	7.56	0
4:36	7.55	0
4:38	7.58	0
4:40	7.56	0.08
4:42	7.55	0
4:44	7.51	0.38
4:46	7.55	0
4:48	7.48	0.75
4:50	7.58	0
4:52	7.59	0
4:54	7.58	0
4:56	7.55	0.28
4:58	7.62	0
5:00	7.56	0.2
5:02	7.56	0
5:04	7.55	0.46
5:06	7.58	0
5:08	7.56	0
5:10	7.58	0
5:12	7.59	0
5:14	7.58	0
5:16	7.55	0
5:18	7.62	0
5:20	7.56	0
5:22	7.56	0
5:24	7.55	0.84
5:26	7.58	0
5:28	7.56	0
5:30	7.55	0
5:32	7.55	0.46
5:34	7.58	0
5:36	7.59	0
5:38	7.58	1.02
5:40	7.55	0
5:42	7.62	0
5:44	7.56	0
5:46	7.58	0
5:48	7.59	0
5:50	7.58	0
5:52	7.55	0.06

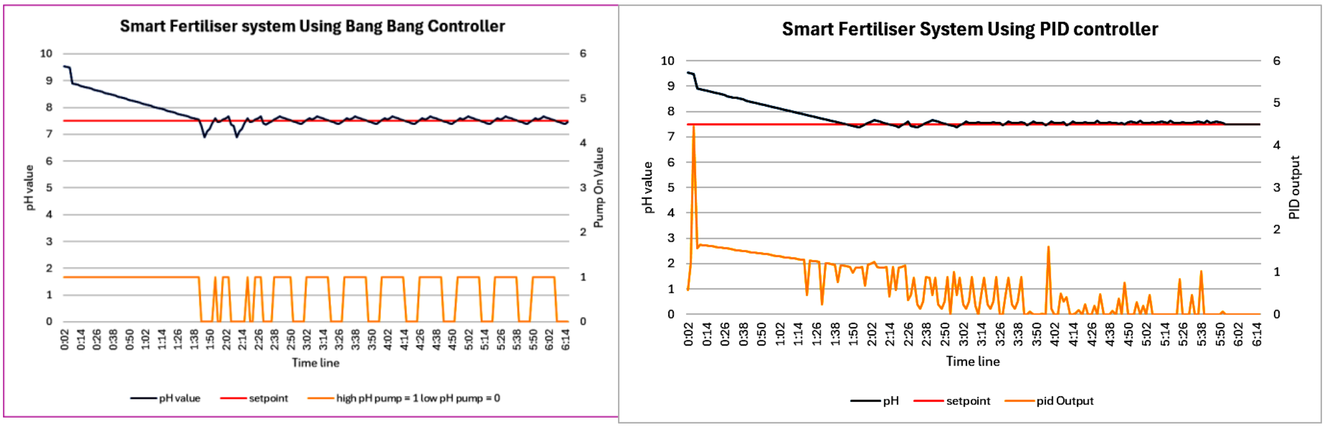
5:48	7.46	0	1
5:50	7.52	1	0
5:52	7.59	1	0
5:54	7.54	1	0
5:56	7.6	1	0
5:58	7.66	1	0
6:00	7.62	1	0
6:02	7.59	1	0
6:04	7.56	1	0
6:06	7.52	1	0
6:08	7.49	0	1
6:10	7.46	0	1
6:12	7.42	0	1
6:14	7.39	0	1
6:16	7.46	0	1

5:54	7.5	0
5:56	7.5	0
5:58	7.5	0
6:00	7.5	0
6:02	7.5	0
6:04	7.5	0
6:06	7.5	0
6:08	7.5	0
6:10	7.5	0
6:12	7.5	0
6:14	7.5	0
6:16	7.5	0

From the both table above, the initial pH value of Bang Bang controller in this experiment is show 9.5 and the high pH pump become activated continuously to reduce the pH degree. Over the length from 00:02 to 01:42, the pH level reduced from 9.Fifty four to 7.32. At 01:44, the excessive pH pump changed into turned off and the low pH pump was activated to prevent the pH from dropping too low, displaying a transition in control approach to maintain the pH around the preferred setpoint. Post 01:54, the pH degree stabilized round 7.6, oscillating among 6.89 and 7.66, that's normal for a Bang-Bang controller because of its on and off nature. This demonstrates the controller's ability to maintain the pH inside a distinct variety regardless of inherent oscillations.

While the PID controller experiment commenced with an preliminary pH value of 9.54 and a PID output of 0.57 at 00:02. The PID controller accelerated the output to make considerable corrections, gradually lowering the pH. By 01:20, the pH had reduced to round 7.54, with the PID outputs reflecting essential modifications. As the pH approached the setpoint, the PID outputs made smaller changes to high-quality-music the steadiness of the pH value. From 02:00 onwards, the pH degrees oscillated barely around the target range, indicating the system's capability to preserve a stable environment through non-stop small corrections.

Both control methods correctly maintained the preferred pH variety, with the Bang-Bang controller attaining this via non-stop pump switching and the PID controller thru gradual, specific modifications. The PID controller supplied more solid manipulate, essential for ensuring the fertilizer's pH remained most effective for chili plant growth. Thus, the selection among Bang-Bang and PID control techniques may be based totally on the specific requirements of the fertilizer gadget, with the PID controller presenting more specific and stable control. The graph shows below is about the plotting point for each controllers.



(a) **(b)**

Fig. 4 *plotting graph of controller (a) Bang Bang; (b) PID*

4. Conclusion

The implementation of a sophisticated smart fertigation system integrating IoT and AI technologies notably complements the precision and efficiency of nutrient transport in chili cultivation. The use of PID controllers is prefer to the Bang Bang controller which using on and off method, offers superior control and stability, main to higher useful resource management and improved productiveness. Thus, this machine represents a massive step in the direction of sustainable and green agriculture practices in Malaysia, with the high capacity to convert chili cultivation and enhance financial resilience. So, in the future work and recommendation, it is important to pay more attention on further optimizing the manipulate algorithms and expanding the machine to encompass extra sensor and actuators for extra comprehensive monitoring and control of the greenhouse surroundings.

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