

PC-BASED PID NUTRIENT MIXING PROCESS FOR FERTIGATION SYSTEM

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*Dengan nama Allah yang Maha Pemurah lagi Maha Pengasih.  
To my beloved, supportive wife Ainun Munirah Kamaruddin,  
and my daughter Nurhana Safiyya*

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## ABSTRAK

Fertigasi merupakan satu teknik bagi membekalkan tanaman dengan baja melalui kaedah pengairan. Ia merupakan teknik pertanian yang moden bagi memaksimumkan hasil dan mengurangkan pencemaran alam sekitar melalui pengawalan penggunaan baja yang cekap seterusnya meningkatkan pulangan ke atas baja yang dilaburkan. Dengan menggunakan teknik fertigasi, masa, jumlah dan kepekatan baja yang digunakan dapat dikawal. Keperluan nutrien tanaman sangat bergantung kepada peringkat biologi pertumbuhan. Ia berbeza dari peringkat pembenihan sehingga menuai. Matlamat projek ini adalah untuk mereka bentuk, memberikan keboleharapan dan mengekalkan proses pencampuran baja fertigasi set A dan set B pada nilai yang diperlukan dengan menggunakan pengawal, PID. Pam kadar aliran yang tepat digunakan untuk menyuntik kedua-dua baja set A dan set B pada kekonduksian elektrik (KE) tertentu, diikuti dengan kadar pengambilan nutrien tumbuhan berdasarkan sistem pengairan berjadual. Kerintangan elektrik campuran baja dijadikan sebagai proksi kepada kebolehubahan nutrien. Keberkesanan sistem diuji melalui eksperimen. Oleh itu prototaip sistem fertigasi berasaskan komputer dibina bagi mengumpul dan menganalisis data pengukuran, (KE). Maklumat sebenar digunakan sebagai bandingan untuk mengesahkan kejituan sistem kawalan PID. Kajian menunjukkan proses pencampuran baja set A, set B dan air menggunakan pengawal PID dapat meningkatkan kecekapan pencampuran baja merujuk kepada nilai yang dikehendaki.

## ABSTRACT

The practice of supplying crops in the field with fertilizers via the irrigation water is called fertigation. It is a modern agro-technique which provides an excellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency, minimizing fertilizer application and increasing return on the fertilizer invested. In fertigation, timing, amounts and concentration of fertilizers applied are easily controlled. The nutrient requirement of crops is very much dependent on the biological stage of growth, varying from seeding to harvest. The goal of this project is to design, provide reliable and maintain a mixing process of fertilizer set A and set B at set point using PID controller. The precise proportional flow rate pump is used to inject both fertilizers set A and set B at predecided electrical conductivity (EC) value followed by plant nutrient uptake rate on a time-base irrigation system. Electrical resistivity of the mixing fertilizer liquid is to be considered as a proxy for the variability of nutrient properties. Validation of a model is determined by experiment. Therefore a prototype of fertigation system based on PC-based is built to collect and analyse the measurement data of EC. The result shows that the mixing process of fertilizers set A, set B and water using PID controller has been able to increase the efficiency of mixing fertilizer level according to the set point.

## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	<b>TITLE</b>	i
	<b>DECLARATION</b>	ii
	<b>DEDICATION</b>	iii
	<b>ACKNOWLEDGEMENTS</b>	iv
	<b>ABSTRAK</b>	v
	<b>ABSTRACT</b>	vi
	<b>TABLE OF CONTENTS</b>	vii
	<b>LIST OF TABLES</b>	x
	<b>LIST OF FIGURES</b>	xi
	<b>LIST OF SYMBOLS</b>	xv
	<b>LIST OF ABBREVIATIONS</b>	xvi
	<b>LIST OF APPENDICES</b>	xvii
<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Overview of the Fertigation System	1
	1.2 Objectives of the Project	4
	1.3 Scope of the Project	4
	1.4 Project Planning	5
	1.5 Thesis Outline	5
<b>2</b>	<b>LITERATURE REVIEW</b>	
	2.1 Introduction	6
	2.2 Fertigation System	6
	2.2.1 Mechanical System Design	7

2.2.2	Electrical System Design	8
2.2.3	Control Algorithm	11
2.2.4	Nutrient Mixing and Irrigation Process	12
2.2.5	Measurement Technique	13
	2.2.5.1 pH Sensor	13
	2.2.5.2 EC Sensor	14
2.3	PID Controller	17
2.3.1	The Proportional Term ( $K_p$ )	18
2.3.2	The Integral Term ( $K_i$ )	18
2.3.3	The Derivation Term ( $K_d$ )	19
2.3.4	Control system component	20
2.3.5	Digital Controller	22
2.3.6	PID Controller Turning	23
	2.3.6.1 Method 1: open loop system	24
	2.3.6.2 Method 2: close loop system	25
2.4	Controller System	27
2.5	Summary of the Chapter	28
<b>3</b>	<b>METHODOLOGY</b>	
3.1	Introduction	29
3.2	System Design	29
3.3	Electrical Development	31
3.3.1	Electric Motor Pump	33
	3.3.1.1 PID Motor Control Test Run	36
3.3.2	Level Sensor	38
3.3.3	Electrical Conductivity (EC) Sensor	40
	3.3.3.1 Conductivity Circuit	41
	3.3.3.2 Design of the Sensor.	42
3.3.4	Electrical Circuit Development	47
3.4	Software Development	48
3.4.1	LabVIEW Interface for Arduino Setup Procedure	48
3.4.2	PID Water Level Controller System	50
3.4.3	PID Salinity Controller System	52

3.4.4	PID Fertilizer Mixing Controller System	54
3.4.5	Operation System Procedure	56
3.5	Mechanical Development	59
3.6	Complete Hardware Construction	61
3.7	Summary of the Chapter	62
<b>4</b>	<b>RESULTS AND DISCUSSIONS</b>	
4.1	Introduction	63
4.2	Fertilizer Mixing Behavior	63
4.2.1	Experiment 1A	64
4.3	EC Sensor	65
4.3.1	Experiment 2A	66
4.3.2	Experiment 2B	67
4.3.3	Experiment 2C	68
4.3.4	Discussions	68
4.3.4.1	Polarization	69
4.3.4.2	Contamination of Probe Surfaces	70
4.3.4.3	Geometry Errors due to Field Effects	70
4.3.4.4	Cable Resistance	70
4.3.4.5	Advantages and Disadvantages of Two Probe	71
4.4	Controller Tuning	71
4.4.1	PID Level Controller Tuning	72
4.4.2	PID Fertilizer Mixing Controller Tuning	75
4.4.3	PID Fertilizer EC Tuning	81
4.4.4	Result Discussion:	84
4.5	Summary of the Chapter	86
<b>5</b>	<b>CONCLUSIONS AND SUGESTION</b>	
5.1	Suggestions for Future Work	87
5.2	Conclusions	87
5.3	Introduction	89
	<b>REFERENCES</b>	<b>90</b>
	Appendices A – B	93-94



**LIST OF TABLES**

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Zigler-Nichols tuning rules for the first method	26
2.2	Zigler-Nichols tuning rules for the second method	26
4.1	The result of Experiment	64
4.2	Advantage and disadvantage of two probe	71
4.3	PID Parameter tuning using Zigler Nichols method	73
4.4	PID Parameter tuning using Zigler Nichols method	77
4.5	PID parameter tuning using Zigler Nichols method	82
4.6	Values of $K_p$ , $T_i$ and $T_d$ for all PID controller module using Zigler Nichols	85

## LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Type of vegetable cultivation method	2
1.2	Traditional automatic fertigation system	2
2.1	Developed architecture of nutrient mixing and irrigation system.	7
2.2	Schematic diagram showing various parts of the system	8
2.3	Fertigation control system	9
2.4	Schematic diagram of the nutrient mixing system for Fertigation	10
2.5	Structure of irrigation fertigation system	10
2.6	Program flow for nutrient mixing, monitoring and irrigating process.	11
2.7	pH Sensor	14
2.8	EC sensor by Atlas Scientific	14
2.9	Electrical resistivity method with an array of four electrodes.	15
2.10	Total schematic diagram of the measurement system	16
2.11	Salinity sensor by a magnetic coil pair	16
2.12	Graph response due to P value alterations change of response for varying $K_p$	18
2.13	Graph response due to I value alterations change of response for varying $K_i$	19
2.14	Graph response due to I value alterations change of response for varying $K_d$	20
2.15	Block diagram of a feedback control system	22
2.16	Digital controller in a closed loop.	22

2.17	Configuration of digital controller in closed-loop	23
2.18	S-shaped response curve.	24
2.19	Oscillations with period $P_{cr}$	26
2.20	LabVIEW-Arduino interaction with physical world	27
3.1	Mechanical and electrical system design	30
3.2	Electrical block diagram	31
3.3	Block diagram close loop PID level controller	31
3.4	DC Diaphragm Pump model (a)PLD – 1206 (China) (b)HF-8367(Taiwan).	33
3.5	MD30B motor driver	34
3.6	Driver and motor pump connection.	35
3.7	Complete installation of DC diaphragm pump	35
3.8	Block diagram of PID motor control	36
3.9	Front panel PID motor control	37
3.10	Voltage Divider Circuit for eTape sensor.	38
3.11	Installation of level sensor.	39
3.13	The block diagram of the electrical conductivity, EC	42
3.13	Electrical conductivity (EC) sensor. (a) Physical of EC sensor (b) Physical of EC Probe	43
3.14	Electrical Conductivity (EC) probe.	44
3.15	Block diagram	45
3.16	Front panel	45
3.17	Complete installations of the EC sensor in the tank.	46
3.18	Complete installation of Arduino Mega 2560 and water Pump	47
3.19	Block diagram of Arduino Palette	49
3.20	Front panel of Arduino Palette	49
3.21	PID level sensor	50
3.22	Programming method to control the level of water in solution tank	51
3.23	Front Panel to control the level of water in solution tank	51
3.24	PID controller design of EC	52
3.25	Programming method to control the level of EC	53
3.26	Front panel to control the level of EC	53

3.27	PID fertilizer mixing controller system	54
3.28	The program to control the mixing ratio of Fertilizer set A and B	55
3.29	Front panel to show the fertilizer mixing process.	55
3.30	Flow chart of the operation procedure of the system	56
3.31	Flow chart of the operation procedure of the system	57
3.32:	The complete front panel as a graphic user interface	58
3.33	Part of the tank system	59
3.34	Part of the tank system	60
3.35	Three units of the system, computer, electronic and pump unit	61
3.36	Complete model of hardware installations	61
4.1	Illustration of the Experiment 1A	64
4.2	The result of Experiment 1	65
4.3	Measurement of solution by EC sensor	66
4.4	Result Experiment 2A	67
4.5	Result Experiment 2B	67
4.6	Result Experiment 2C	68
4.7	Accumulation of ionic species at electrode surface	69
4.8	Field line between two probe	70
4.9	Result for $K_p=K_{cr}$ where output of the system will oscillate with period $P_{cr}$ .	72
4.10	P tuning Result	73
4.11	PI tuning result	74
4.12	PID tuning result	74
4.13	P automatic tuning result	74
4.14	PI automatic tuning result	75
4.15	PID automatic tuning result	75
4.16	Result for $K_p=K_{cr}$ where the system's output will oscillate with period $P_{cr}$	76
4.17	P tuning result using Zigler Nichols	78
4.18	PI tuning result using Zigler Nichols	78
4.19	PID tuning result using Zigler Nichols	79
4.20	P automatic tuning result	79
4.21	PI automatic tuning result	80

4.22	PID automatic tuning result	80
4.23	Result for $K_p=K_{cr}$ where the system's output will oscillate with period $P_{cr}$	81
4.24	P tuning result using Zigler Nichols	83
4.25	PI tuning result using Zigler Nichols	83
4.26	PID tuning result using Zigler Nichols	84

## LIST OF SYMBOLS

$V$	-	Voltage
$I$	-	Current
$R$	-	Resistance of the solution
$\kappa$	-	Conductivity in S/cm
$G$	-	Electrical conductance
$K$	-	Cell constant in $\text{cm}^{-1}$
$C$	-	Salt Concentration in water
$A$	-	Factor composition of the particular concentrated solution
$f$	-	Injection rate of the stock solution dispensers in $l/s$ .
$V_n$	-	Volume of nutrient solution for total number of plant
$Q$	-	Pump Flow Rate
$n$	-	Total number of plant in irrigation pipeline
$V_i$	-	Total volume of nutrient solution injected to each plant
$T_{pump}$	-	ON period of pump in seconds
$P_{out}$	-	Proportional term of output
$K_p$	-	Proportional gain
$K_i$	-	Integral gain
$K_d$	-	Derivative gain
$P_{cr}$	-	Period of oscillations
$T_i$	-	Integral Time of PID controller
$T_d$	-	Derivative Time of PID controller
$K_{cr}$	-	Critical value of PID sustained oscillations

## LIST OF ABBREVIATIONS

A/D	-	Analog to Digital Converter
CV	-	Control Variable
DAS	-	Data Acquisition System
DIT	-	Drip Irrigation technique
DFT	-	Deep Flow Technique
D/A	-	Digital to Analog Converter
D.C	-	Direct Current
<i>EC</i>	-	Electrical Conductivity
<i>EC<sub>w</sub></i>	-	Current Electrical Conductivity
<i>EC<sub>d</sub></i>	-	Desired Electrical Conductivity
EFT	-	Ebb and Flow Technique
GFT	-	Gravel Flow Technique
GUI	-	Graphical User Interface
MV	-	Manipulated Variable
NFT	-	Nutrient Film Technique
pH	-	Power of Hydrogen
P	-	Proportional Controller
PI	-	Proportional + Integral Controller
PV	-	Process Value
PID	-	Proportional + Integral + Derivative Controller
PWM	-	Pulse Width Modulation
RMT	-	Root Mist Technique
SP	-	Set Point
SAT	-	Static Aerated Technique.
USB	-	Universal Serial Bus
ZN	-	Zigler Nichols

**LIST OF APPENDICES**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	Project planning schedule	95
B	Schematic block diagram of Arduino Mega 2560	96



## **CHAPTER 1**

### **INTRODUCTION**

This chapter discusses on the definition of the fertigation system, the purpose and the importance of the project. The objectives of project, scope of project and thesis outline will also be presented in this chapter.

#### **1.6 Overview of the Fertigation System**

There are many techniques in vegetable cultivation. Figure 1.1 shows the three major techniques used in Malaysia which are conventional, organic farming and hydroponic. Hydroponic techniques grow from day to day replacing existing methods.

Hydroponic is the process of growing plants in media such as coco peat, rock wool, gravel, or liquid, with added nutrients but without soil. There are many methods as shown in Figure 1.1. One of the famous techniques is fertigation which is the technique of supplying fertilizer to crops through an irrigation system by injection. In fertigation technique, it has two sets of fertilizer. Both of fertilizers must be mixed and stirred with the ratio 1:1 respectively into water. The illustration of this system is shown in Figure 1.2. The nutrient of the solution will be measured by the EC measurement device to make sure the level of nutrient is not more than the crop requirement.

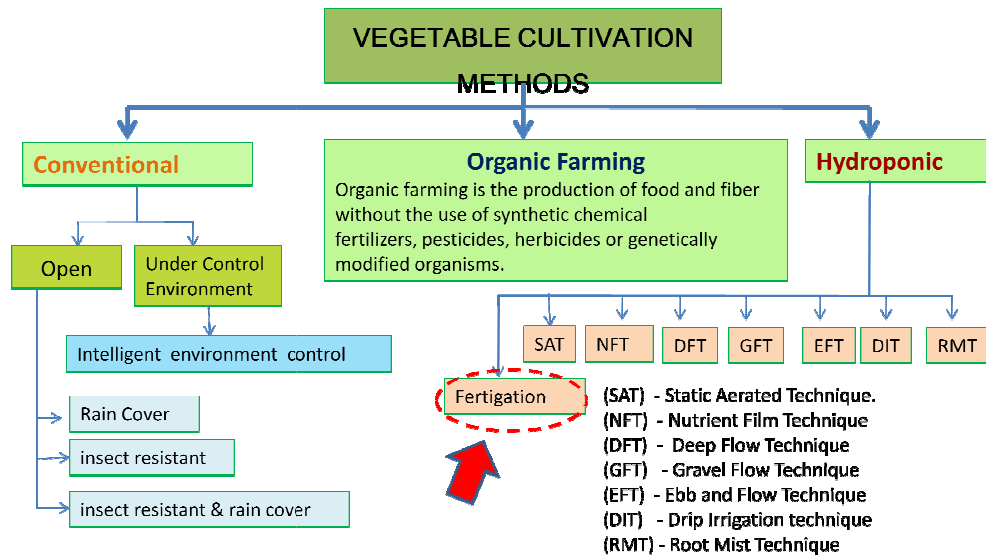


Figure 1.1: Type of vegetable cultivation method

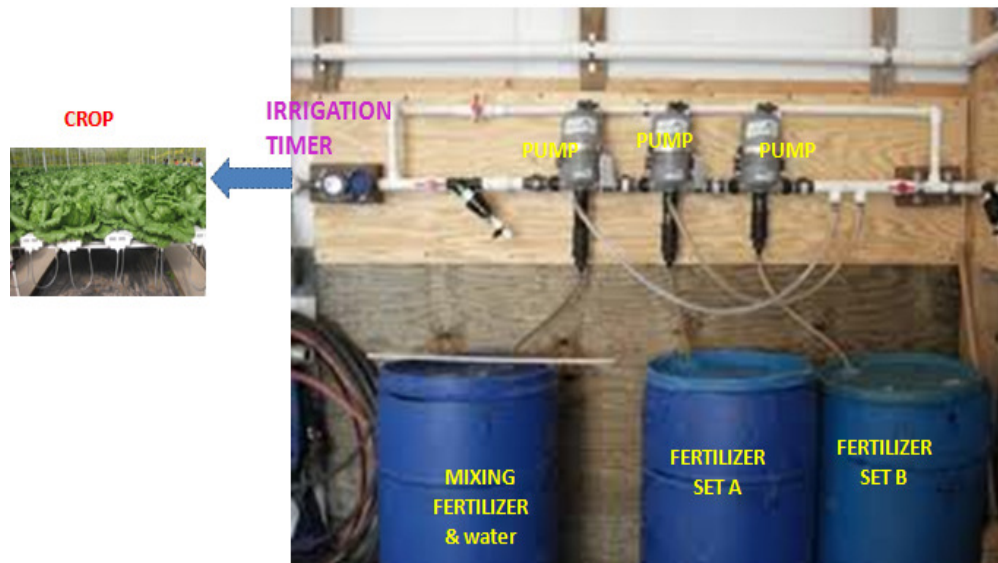


Figure 1.2: Traditional automatic fertigation system

The advantages of supplying mineral nutrients to crop roots using fertigation include:

- i. Reduced delivery costs (no need to broadcast fertilizers, leading to less soil compaction in the inter-row areas, less fuel usage and lower labor requirements).
- ii. Greater control over where and when nutrients are delivered, leading to the greater fertilizer use efficiency.
- iii. More control over crop behavior through targeted application of specific nutrients during particular stages of crop development.
- iv. Potential to reduce fertilizer losses (due to immobilization within or leaching below the root zone) by supplying small amounts constantly.

Disadvantages of supplying mineral nutrients to crop roots using fertigation include:

- i. Greater capital costs associated with the equipment needed to dissolve and inject the fertilizer into the irrigation water.
- ii. Higher operating costs associated with using technical grade fertilizers as opposed to agricultural grade fertilizers.
- iii. Chemical reactions between some types of fertilizers when mixed, potentially causing significant equipment blockages.

## 1.7 Objectives of the Project

The aims of this project are to design, provide reliable and maintain a mixing process of fertilizers set A and set B at set point using PID controller. Specifically the objectives of this project are:

- i. To study on the process of mixing fertilizers set A and set B in the fertigation system
- ii. To establish the relationship between electrical conductivity, salinity of mixture of fertilizer set A and set B and design an EC sensor using carbon probe.
- iii. To design and develop a low cost PID controller for the mixing process of fertilizer set A and set B to determine certain level of EC.

## 1.8 Scope of the Project

This project is divided into two parts, which are:

### Part 1: Hardware development

Firstly, literature studies on the concept of automatic fertigation techniques are revised. Microcontroller Arduino Mega 2560 is used to interface with the actuator and sensor. The simple and low cost Electrical Conductivity sensor (EC) will be proposed to measure the EC in the solution tank. The correlation between actual value of EC vs salinity is determined experimentally using conductivity probe. The data are used as a calibration of the EC sensor.

### Part 2: Software Development

This project focused on PID controller design using Arduino-LabVIEW. Microcontroller type Arduino Mega 2560 is used to interface with the actuator and

sensor. A model of fertigation system based on a PC-based will be built to evaluate the performance of PID controller.

## **1.9 Project Planning**

This project was implemented based on the project planning schedule. The project started from Sept 2013 and ended in May 2014. The project planning schedule is presented in Appendix A.

## **1.10 Thesis Outline**

Chapter 1 presents the overview of the automatic fertigation system, the objectives of the project, project schedule and thesis outline.

Chapter 2 covers the literature review on the fertigation technique, the principles of fertigation hardware and software and PID controller system.

Chapter 3 describes in details the development of PC-based PID nutrient mixing process on fertigation system methodology, and also hardware and software development.

Chapter 4 presents the results of the experiments and measurements. All the results will be discussed in details.

Chapter 5 discusses the overall conclusions and suggestions for future work.

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