AUTOMATED WATER SPRINKLER FOR INTELLIGENT GREENHOUSE

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Electrical & Electronic Engineering Programme
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Approved by,

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the originality work contained herein have not been undertaken or done by unspecified sources or persons.

(Dzulfadly Bin Johare)

ABSTRACT

The project is about the Automated Water Sprinkler for Intelligent Greenhouse. The research made used of Programmable Logic Controller (PLC) which was regarded as the heart of control system in automation. Sensors, sprinklers and valves were interfaced to the PLC in order to have sufficient amount of water for the eight flower beds in the greenhouse. Likewise added features such as curtain, fan and actuators (for opening and closing roof) were interfaced to PLC to make the greenhouse intelligent. Also, calculations were done to find the amount of irrigation required based on the percentage of the evaporation rate in Malaysia and crop factors to 8 chosen type of flowers for this project.

ACKNOWLEDGEMENT

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I would also like to express my appreciation to Md Afifuddin and Wan Sadik Hakim for voluntarily giving me numerous suggestions in order to complete the prototype and to improve the system. I am grateful for their contribution. There are others to thank, Khirul Akmal and Muhammad Rizal whose contributions are extremely valuable.

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CHAPTER 1
INTRODUCTION

1.1. Background Of Study

An adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Various methods can be used to supply irrigation water to the plants. Each method has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local circumstances. A simple irrigation method is to bring water from the source of supply, e.g. a well, to each plant with a bucket or a watering can. This is an ineffective way of irrigating plant and can be very time-consuming. More sophisticated methods can be used are: sprinkler irrigation, surface irrigation and drip irrigation. To be specific, automated water sprinkler for greenhouse is the main topic for this proposal.

Greenhouse produce high quality crops, high yields and year-round excellence that cannot be achieved in the open field. Greenhouse grown crops represent a shift from extensive to intensive production. In greenhouses, the plants must be provided with optimal conditions, both above and below ground, down to the underlying roots. Control of temperature, relative humidity, airflow and atmosphere composition, water and fertilization supplies are imperative, and oxygen levels near the roots must be maintained. In order to maintain the quality of the crops, reliable water irrigation system is needed.

Automated water sprinkler is a new applicable technology in horticulture sector. The technology has been used in Europe and America but in Malaysia, it still need attention from the government especially agriculture sector to introduce it to farmers and gardeners. The automated water sprinkler can be used whether at garden, plantations or in greenhouses.

Automated water sprinkler functions just like the common water sprinkler but it is more "intelligent" because the automated water sprinkler has a program and sensor installed inside. The automated water sprinkler will sprays water when it detects the soil moisture is at low level. This means that whenever the soil is dry, the sensor detects and sends the data to the program which will decide the volume of water that will be supplied to the plant.

A prototype of the automated water sprinkler will be designed during the research. It is hope that all greenhouses in Malaysia will use the same concept of this sprinkler so that it will increase the productivity of the plant and at the same time reducing the use of workers to water their plant. With this system, less supervision is needed for the greenhouse.

1.2. Problem Statement

The title of this project is *Automated Water Sprinkler for Intelligent Greenhouse*. Enough water needs to be supplied to the plant in the greenhouse. Supplying less or more water than needed by the plant will cause low quality in production. Basically, the aim for this project is to develop a model or prototype of the automated water sprinkler by making use of Programmable Logic Controller (PLC), sensor, valve, piping and sprinklers. Further considerations and studies have to be made on soil, plant, water and greenhouse for the model to work efficiently. Intelligent greenhouse is needed so that people will have more leisure time besides reducing the use of workers.

1.2.1 Programmable Logic Controller (PLC)

In automated system, the PLC is commonly regarded as the heart of the control system. With a control application program (stored within the PLC memory) in execution, the PLC constantly monitors the state of the system through the field input devices' feedback signal. It will be based on the program to logic to determine the course of action to be carried out at the field output device.

Intelligence of an automated system depends much on the ability of a PLC to read in the signal from various types of automatic sensing and manual input field devices. For detection of workpiece, monitoring of moving mechanism, checking on pressure or liquid level and many others, PLC will have to tap the signal from the specific automatic sensing devices like proximity switch, limit switch, photoelectric sensor, level sensor, and level sensor and so on. Types of input signal to the PLC would be of ON/OFF logic or analogue. In this project, the input device would be soil moisture sensor or Rain Sensor Device (RSD).

The PLC has to be interfaced with the valve as the final element in the system which will guard the opening and closing of the valve. Finally water will be supplied to the plants through sprinklers.

1.2.2 Sensor

There are various sensors that can detect the soil moisture and rain detector in the market. Careful study on these sensors has to be done in order to select the most reliable sensor that can fit the system well.

1.2.3 Valve

Valves are needed for opening and stopping the water from supply to the plant. The valves will receive direction from the PLC whether to open or close.

1.2.4 Sprinkler

There are many types of sprinkler and two of them are water jet and micro sprinklers. Due to several types of sprinklers, attention to the type plant and the way they are planted is needed because the types of sprinkler depend on both of the factors. From the information collected, water supplied to the plant need proper filtration to protect small drip on sprinkler orifices from clogging. Clogging will cause disastrous results in uniformity.

1.2.5 Landscape water and nutrients requirements

Landscape water and nutrient requirements are not included for this project but it is important to consider both of the landscape and nutrient requirements. By knowing the size of the greenhouse and amount of water for the plants, a proper calculation of cost needed for this automated system can be done.

1.2.6 Piping

Piping also plays important roles for greenhouse. There are 3 types of piping suitable for greenhouse: Low-density black polyethylene, Schedule 80 PVC and dark painted Schedule 40 PVC. Low-density polyethylene is widely recommended because of its sunlight inhibiting properties, flexibility and low cost. White PVC is not recommended because it has tendency for algae to grow within it. Gray schedule 80 PVC is also recommended due to its structural capabilities as well as its color and sunlight inhibitors.

The water sprinkler will work automatically when it receives data from the sensor. The purpose of sensor is to prevent unnecessary landscape watering. Sensor of the system will detect the soil moisture whether it is dry or not by measuring the electrical resistivity of the soil. The drawback is that soil resistivity depends on salt concentration as well as soil moisture concentration. Then, the sensor will send data to the PLC which acting like the brain of the system will decide the volume of water to be supplied to the plant. The PLC will trigger the valve to open and supply water to the plant through the sprinklers.

1.3. Objectives and Scope Of Study

1.3.1 Objective

The objective of this project is to develop a model or prototype of the automated water sprinkler for intelligent greenhouse by using PLC, sensor, valve, piping and sprinkler for greenhouse. Besides, further considerations and studies have to be made on soil, plant, water and greenhouse.

1.3.2 Scope of Study

The type of plant to be used in this project is flowers. Any kind of flowers such as roses, carnation, sunflowers, etc can be planted in the greenhouse. But for the project, flowers to be planted in the Greenhouse are:

- Roses
- Daisies
- Hibiscus
- Orchids
- Cyclamen
- Chrysanthemum
- Marigold
- Tulips

The type of soil to be used depends on the type of flowers selected. The amount of water needed by each type of flowers is critical. Thus the amount of water must be calculated correctly.

Greenhouse selected should have some special features like it has a roof and curtains that can be opened and closed during rain and hot weather. It also has cooling system such as fan to ensure all the flowers get the optimal temperature for growing. The reason why all the special features are included in the scope of study is because of transpiration of the flowers. This is to ensure that the water supplied to the flowers do not loss due to the transpiration process since that Malaysia has tropical climate. Maybe only small amounts of water will loss during transpiration process.

This project has been divided into 2 major parts: Research and study and prototyping together with interfacing.

The first part which is research and study has been done for last semester where all information about sensors, valves, piping and sprinklers are being gathered for selecting the appropriate devices to be used in the prototype. Programming on the PLC also has been done for last semester in order to get the program works before interfacing with all the devices together.

The second part is where all components and the PLC are being integrated together and works as expected. This action is planned for this semester. All the sensors to be used in prototyping have been gathered and will be tested to ensure all the sensors work. A complete wiring diagram will be designed to ensure good connection between the sensors, PLC and the output such as water valve, motor, fan and pneumatic valve.

CHAPTER 2
LITERATURE REVIEW / THEORY

2.1. Literature Review

Greenhouse grown crops is an intensive production which produce high quality crops, high yields and year round excellence that cannot be achieved in the open field. The plants must be provided with optimal condition both above and below ground, down to the underlying roots. Control of temperature, relative humidity, airflow and atmosphere composition, water and fertilization supplies are imperative, and oxygen levels near the roots must be maintained.

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.

Sprinkler irrigation is suited for most row, field and tree crops and water can be sprayed over or under the crop canopy. However, large sprinklers are not recommended for irrigation of delicate crops such as lettuce because the large water drops produced by the sprinklers may damage the crop.

Sprinkler irrigation is adaptable to any farmable slope, whether uniform or undulating. The lateral pipes supplying water to the sprinklers should always be laid out along the land contour whenever possible. This will minimize the pressure changes at the sprinklers and provide a uniform irrigation.

Sprinklers are best suited to sandy soils with high infiltration rates although they are adaptable to most soils. Sprinklers are not suitable for soils which easily form a crust. If sprinkler irrigation is the only method available, then light fine sprays should be used. The larger sprinklers producing larger water droplets are to be avoided.

2.2. Theoretical Framework

Based on the above information, the best and less cost type of sprinkler should be used in this project. Also, the soil moisture sensor has to be very responsive which means that when the sensor detects the soil moisture is low, the time it needs to trigger PLC must be fast. The valve to be selected for this project should be the one that operate efficiently and has specification that will not allow the backflow of water from going back to the source. All the part must be interfaced with the PLC to build the system. The programming part must be perfect during prototyping to ensure the effectiveness of this project. The system must be well suited for the intelligent greenhouse to achieve the objective of this project.

CHAPTER 3
METHODOLOGY

The methodology and procedure used to conduct the research were divided into four main parts:

3.1 Literature Review and Information Gathering

- Information regarding the automated water sprinkler for greenhouse was gathered.
- The relevant information on greenhouse, sensors, volume of water needed for flowers and valves was studied thoroughly to support data for this project.
- Method used for information gathering is shown in Figure 1.

3.2 Programming

- Programming was done by using the PLC. All knowledge regarding the PLC is to be used and all relevant information on PLC collected will be analyzed.
- Programming was done by using PLC and the modeling made used of PLC, sensor, valve and sprinkler.
- Method used in developing PLC program is shown in Figure 2.

3.3 Modeling Development

- Developing the prototype for this project was done for the second semester.
- All parts were integrated with PLC and tested through some procedure (See Figure 3).
- Finally, all the parts were integrated together and perform as a full system.

3.3 Data Analysis and Comparison

- The relevant data collected from any source such as websites and other reference books were analyzed

- Comparisons on the effectiveness of the model were done with the real product available in market (if any).

3.4 Report Preparation

- After all the result have been analyzed and collected, the report for the research was prepared as part of the requirement for the course. Besides that, the report also serves as the reference for further development of the respective field of study.

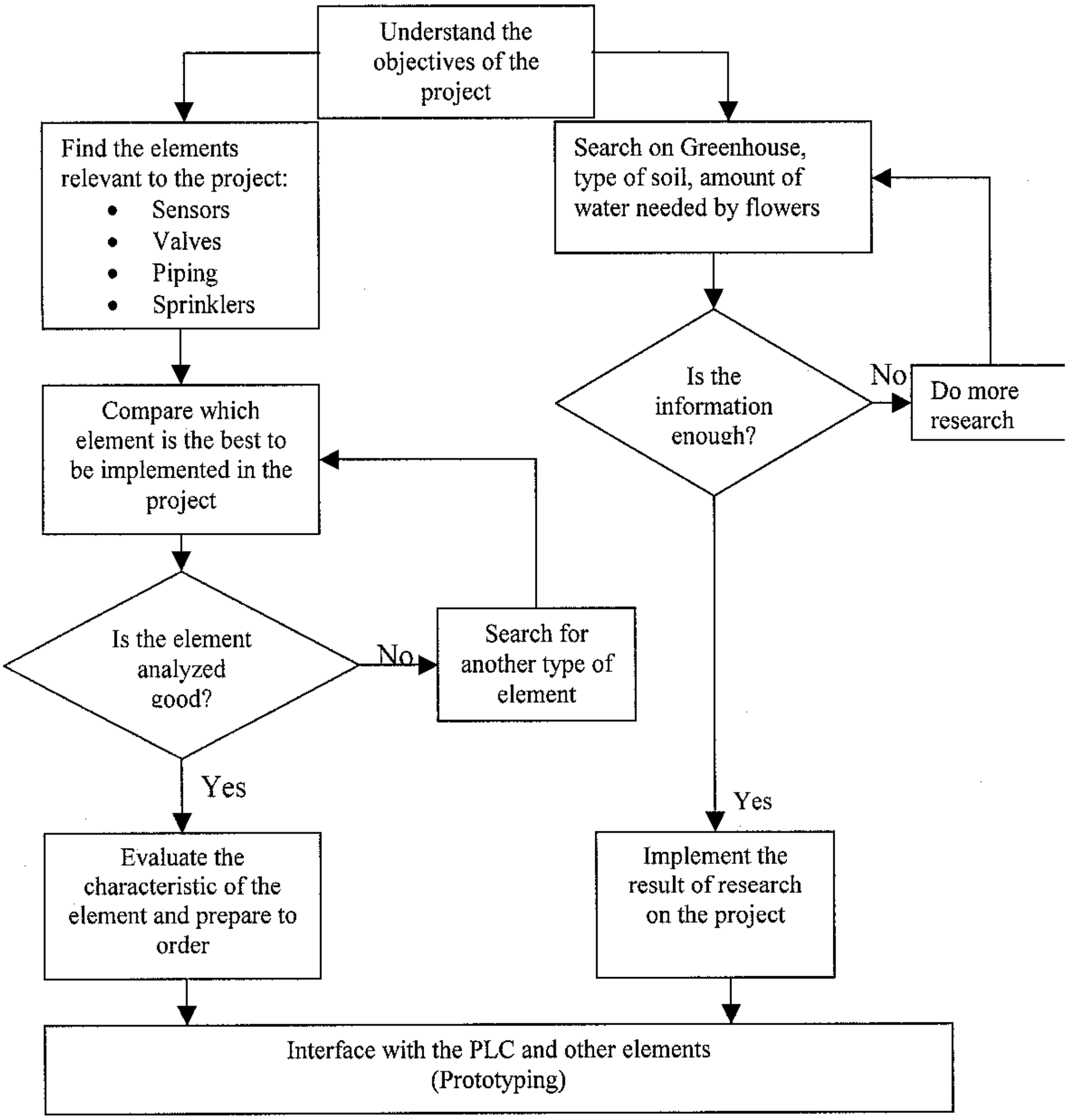


Figure 3.1: Method used in information gathering

The method used in gathering information is shown in Figure 3.1. First step was to understand the objective of the project. After the main objective was clearly understood, research on several important information regarding Greenhouse and elements needed for implementing the project was done. The research was divided into 2 parts:

- Research on Greenhouses, type of soils, amount of water needed by flowers
- Research on elements needed for the automated water sprinkler system

For the first part, information about the Greenhouses, type of soils and amount of water needed by flowers was done. Then, all the information was analyzed further whether sufficient or not. If sufficient, all the information gathered can be the basis for implementing the automated water sprinkler. If not enough, further researches were done.

For the second part, research was done for all the elements needed to implement the automated water sprinkler. All information regarding the sensors, piping, valves, sprinklers were evaluated and analyzed for selecting the best equipment to be implemented for the system. Finally, the last part was integrating all the equipments together for prototyping.

To implement the programming on PLC, the steps were given in Figure 3.2. First, the requirement of the control system must be understand carefully. Then, flowchart regarding the control system was implemented to ensure the program work in orderly flow. All the inputs and outputs were listed and the flowchart was translated into ladder diagram. Next, the ladder diagram was simulated and tested through PLC kit until the program works well. Finally, the program was stored in the EPROM and the drawing was systematically documented.

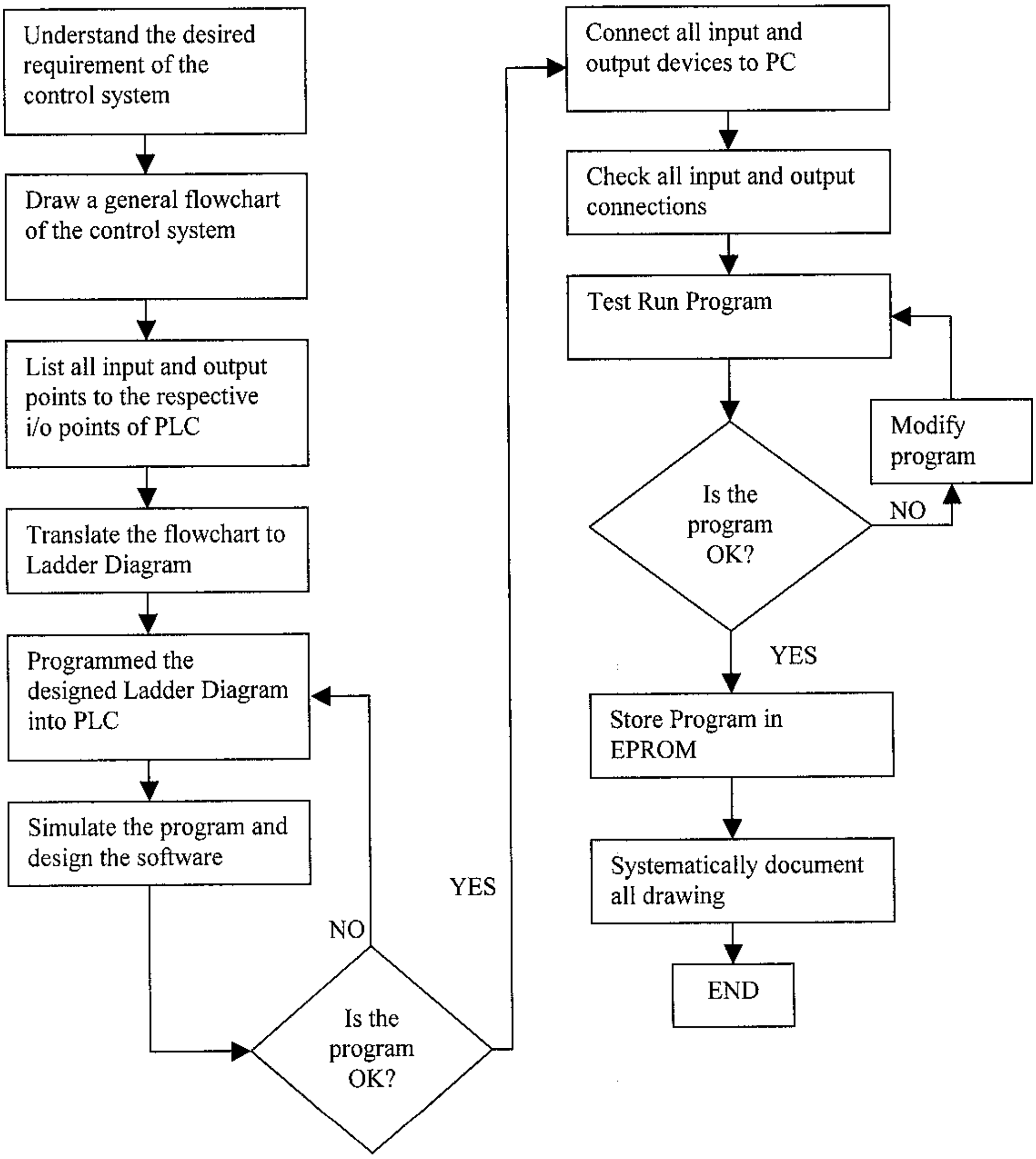


Figure 3.2: Method used in developing PLC

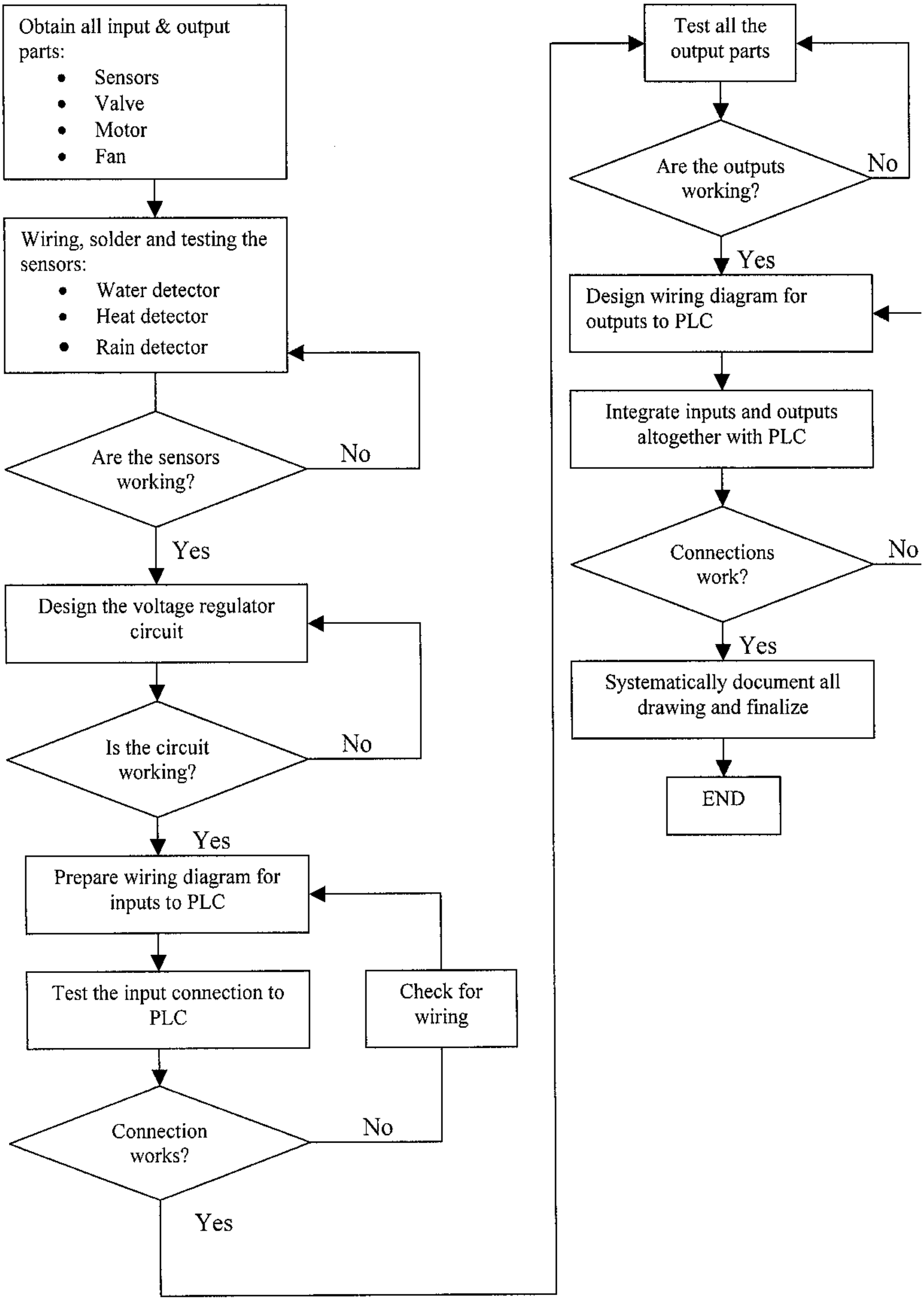


Figure 3.3: Prototyping procedure

The method used in prototyping the model is shown in Figure 3.3. The first step was to obtain all the inputs and outputs part needed for prototyping. The included inputs were:

a. Water detector
b. Heat detector
c. Rain detector

When all the sensors were available, they were soldered and tested until it worked. The PLC can supply 24VDC voltage but all the sensors only need 9VDC supply. Then, wiring diagram was designed to develop connection between those inputs and PLC. The connection between inputs and PLC were tested. When the inputs were all ready, all the output parts were tested. The outputs are:

a. Valve
b. Motor
c. Fan
d. Pneumatic valve

The outputs were tested until all of them work properly. Then, wiring diagram for the outputs was design. All inputs and outputs were connected to the PLC and tested for their connection. All the connections tested until they succeed. Finally, all the drawing were properly documented and finalized.

CHAPTER 4
ANALYSIS OF DATA AND RESULTS

There are 8 main parts discussed in this section. First, the Greenhouse and its specifications which differentiate it from open gardening. Second, the information about volume of water needed by flower was analyzed. Several important formulas were studied. Third, types of sensors were compared to each other to show which sensor was the best and can be used in the project. Fourth, several types of valves were evaluated and compared to each other to select the one that can be implemented for the project. Fifth, the programming part was discussed and the flowchart of the suggested system. Next was the type of sprinkler and its layout. Finally is the system modeling and cost estimation for the real system.

4.1 Greenhouse

Greenhouses must be transparent in order to provide the plants with the maximum sun radiation required for photosynthesis. The area enclosed with transparent enclosure will provide distinct internal climate. The internal radiation level is lower than the external radiation level depending on the factors such as type of shading material, sun inclination and cleanliness of the transparent surface.

4.1.1 Basic Terminology

- Greenhouse span

  The distance between two gutters

- Pole distance

  The distance between poles located along the gutters.

- Greenhouse Height

  The height of gutters above the ground.

- Foundation

  Elements connecting the structures to the ground

- Main Poles

Poles connecting the foundation to the roof structures

4.1.2 Characteristics and Properties of Structures

- Wide variety of structures for various agricultural needs such as vegetables, flowers, packing houses, poultry pens and fish ponds.
- Modular structures suitable for all types of flexible and hard coverings.
- Prefabricated designs and structures ready for immediate or future installation of all modern technological systems and equipment without structural alternations.
- Wide variety of structures suitable for all weather conditions, with the options of appropriate alternatives to suit unusual climates or individual requirements.
- Choice of gutter heights ranging from 2.5m to 5.5m.
- Choice of gable spans ranging from 6m to 12.8m.
- Structures capable of withstanding gusts of wind from120-240 km/hr.

4.1.3 Additional Features

- The roof of the Greenhouse is open when it is not raining to provide enough light to the flowers. The roof will close when rain detector detects rain.
- The curtain in the greenhouse is open when temperature is not too hot. If the temperature is too hot, the curtain will automatically close.
- The fan operation depends on the same temperature sensor. When the temperature in the Greenhouse is too hot for the flowers, the fan will operate.

4.2 Importance Of Water To Flowers

4.2.1 Photosynthesis process

Water, light and carbon dioxide are the three basic element needed by plant for photosynthesis process. Photosynthesis is the process of converting light energy to chemical energy and storing it in the bonds of sugar. This process occurs in plants and some algae. Plants need only light energy, CO_2, and H_2O to make sugar. The process of photosynthesis takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis.

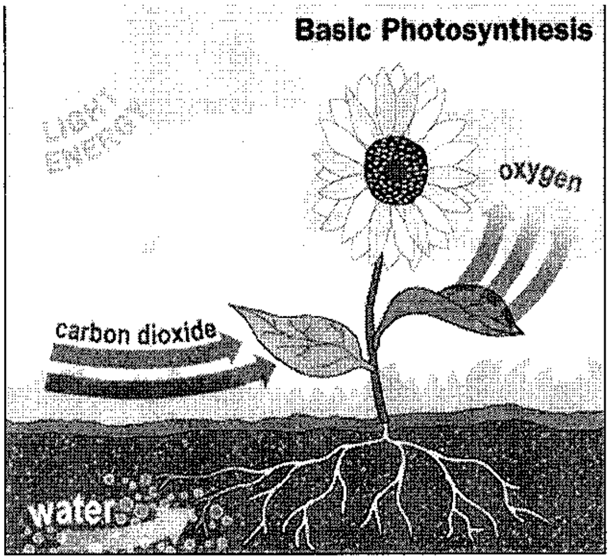


Figure 4.1: Basic photosynthesis process

Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems, etc. The parts of a typical leaf include the upper and lower epidermis, the mesophyll, the vascular bundle, and the stomates. The upper and lower epidermal cells do not have chloroplasts, thus photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The stomates are holes which occur primarily in the lower epidermis and are for air exchange: they let CO2 in and O2 out. The vascular bundles or veins in a leaf are part of the plant's transportation system, moving water and nutrients around the plant as needed. The mesophyll cells have chloroplasts and this is where photosynthesis occurs.

4.2.2 Water absorbs by root

i. The Root tip is covered by a Protective Root Cap, which covers the Apical Meristem (See Figure 4.5).
ii. The Root Cap produces a Slimy Substance that functions like Lubricating Oil, allowing the root to move more easily through the soil as it grows.

iii. Cells that are crushed or knocked off the Root Cap as the root moves through the soil are replaced by new cells produced in the Apical Meristem, where cells are continuously dividing.

iv. Roots do not absorb water and minerals through a smooth Epidermis. Tiny, hair like projections called Root Hairs on the epidermis absorb water and dissolved minerals from the soil. Root Hairs also increase the Surface Area of the Plant Roots.

v. The Core of a root consists of a Vascular Cylinder. The Vascular Cylinder contains Xylem and Phloem. Surrounding the Vascular Cylinder is a band of Ground Tissue called the Cortex. Outside the Cortex is the Epidermis.

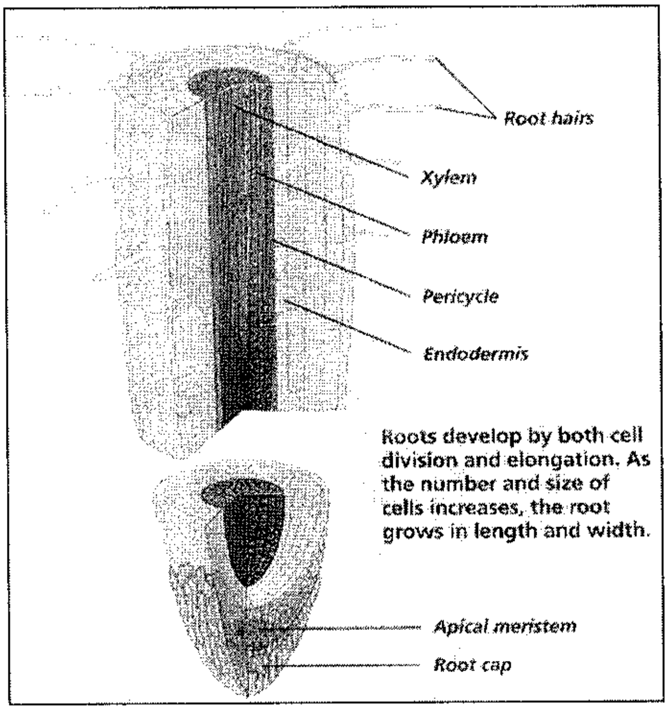


Figure 4.2: Inside the plant root

Figure 4.6 shows how root hairs absorb water and mineral. Water and mineral ions move into the root along two pathways:

i. Mineral ions and water molecules enter root hairs and travel through the cells of the cortex by a process called osmosis. Water also flows between the cells of the cortex.

ii. Nutrients dissolved in water can flow between the parenchyma cells directly into the root cortex, then through the cells of the endodermis

Absorbed water will be used in transpiration, photosynthesis and transportation process to carry minerals to every part of the plant.

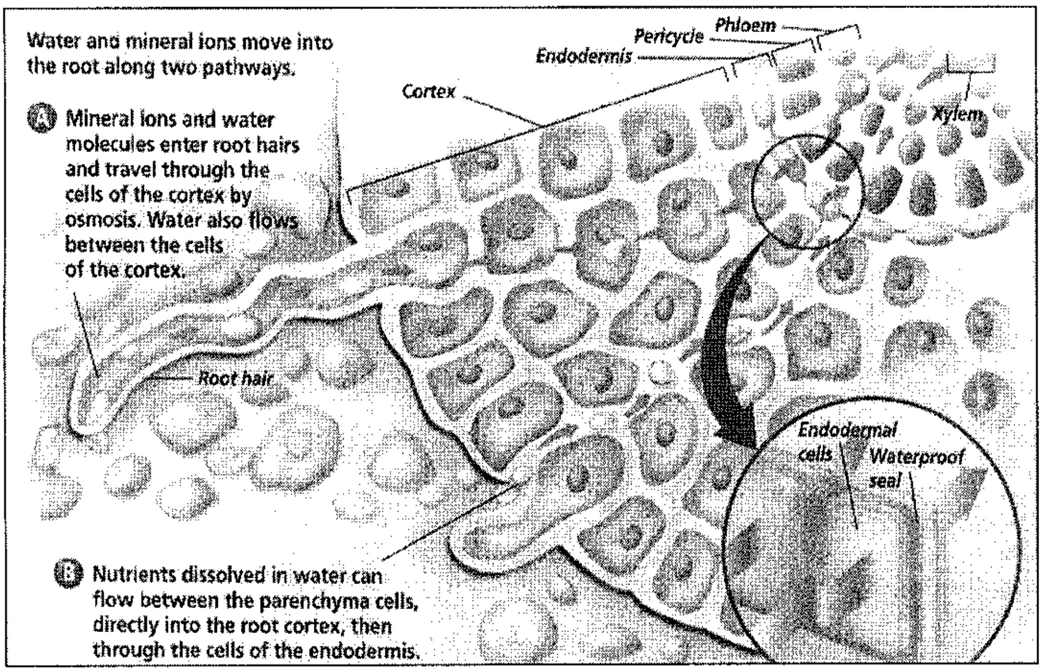


Figure 4.3: How plant absorbs water

4.2.3 Volume of water needed by flowers

Flood irrigation is not very suitable for flowers. It is usually more suitable for plant like vegetables. Overhead watering is not recommended because water splash on the soil may result in disease transfer. Also, overhead watering may damage the flowers, causing spotting on petals. Some type of sprinkle irrigation which places water uniformly around the plant is usually recommended.

There are a few methods for irrigation system but the method discussed is evaporation replacement. This method calculates the amount of irrigation required based on a percentage of the evaporation rate. The percentage used is called the crop factor. All crop factors will vary according to irrigation method, plant size, plant variety and stage of growth. There are a few crop factors for native flowers in Australia:

Crop factors for native flowers in Western Australia	
Crop type	Evaporation replacement % crop factors
Banksia	40 to 50
Boronia	75 to 100
Leucadendron	40 to 50
Pimelea	40 to 50
Protea	40 to 50
Waxes	75

Table 4.1: Crop factors for native flowers in Western Australia

By knowing the crop factors of the flowers, the calculation for irrigation can be done. For example, calculation of water requirement for a wax plant with 1.5m^2 area in January:

Daily evaporation in January = 9.0 mm

Crop factor = 0.75 (from Table 4.1)

Dripper flow = 2 x 4 liter per hour drippers per plant

Quantity of water in liters per plant = mm evaporation x area x crop factor

= 9.0 mm/day x 1.5 x 0.75

= 10.1 liters/day/plant

$$\text{Hrs of irrigation / day} = \frac{Quantityrequired(l\,/\,plant)}{Sprinklerflow(l\,/\,plant\,/\,hour)}$$

$$= \frac{10.1 \text{ l/plant}}{8 \text{ liters/hour}}$$

= 1.25 hours/day

4.2.4 Evaporation Rate in Malaysia

Normal evaporation rates were recorded over the whole places in Malaysia from 1st October 2004 until 10th October 2004. Most places in Malaysia recorded evaporation rates of between 3mm to 4mm per day (See Appendix D). Higher evaporation rate of between 4 to 5mm per day was recorded over coastal Terengganu, east Pahang, southeast to south Johore, most parts of Selangor, west Negeri Sembilan, west Malacca, parts of west Sarawak and northern & part of west Sabah. On the other hand, the highland areas of northwest Pahang, southwest Kelantan & east Perak, northern Kedah, Langkawi Island and Perlis recorded lower daily evaporation rates of between 1.7mm to 3mm.

Calculation of water requirement for rose plant with 1.5m^2 area in October:

Daily evaporation in October = **4.0 mm**

Crop factor = **0.5**

Sprinkler flow = **3 liter per hour**

Quantity of water in liters per plant = mm evaporation x area x crop factor

= 4.0 mm/day x 1.5 x 0.6

= **3.6 liters/day/plant**

$$\text{Hrs of irrigation / day} = \frac{Quantityrequired(l/plant)}{Sprinklerflow(l/plant/hour)}$$

$$= \frac{3.6(l/plant)}{3(l/hr)}$$

= **1.2 hrs / day**

Flower	Irrigation time	Interval
Roses	1 hour	once a day
Hibiscus	1 hour	twice a day
Daisy	20 minutes	once in 3 days
Chrysanthemum	20 minutes	once in 3 days
Orchid	15 minutes	once in 2 days

Table 4.2: Several type of flowers with irrigation time and interval

By knowing the soil types and root zone, irrigation system can be designed more properly and placement of soil moisture sensor can be determined correctly. Heavier soil types require less frequent irrigation as they can store more water which will supply plants for longer periods. Sandier soil requires more frequent irrigation because they are not capable of storing more water. Table 4.3 shows the amount of water readily available to plants growing in different soil types. Plants can extract 30 to 50 per cent of total available soil moisture before they become stressed (see Figure 4.7).

Estimated readily available water	
Soil type	Readily Available Water (RAW) mm/m of soil
Coastal plain sands	20
Loamy sand	35
Sandy loam	50
Loam	60
Clay loam	70
Clay	60

Table 4.3: Estimated readily available water

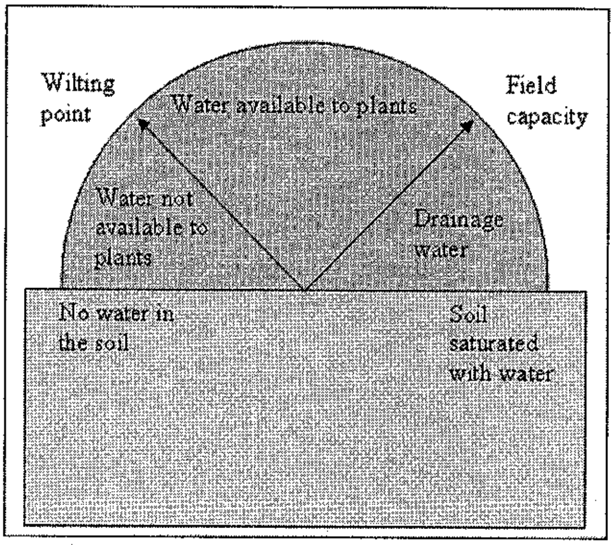


Figure 4.4: Relationship between moisture levels in the soil

As well as soil type, effective root depth from which plant can extract water also affects the readily available water. Young plant may have an effective root depth of 40 cm and older plants in deep sands may have an effective rooting depth as deep as 1 m. The aim is to refill Readily Available Water (RAW).

4.3 Sensor

There are 3 types of sensors:

i. MS-100 Moisture sensor
ii. HMS 9000 Capacitive moisture sensor
iii. Tensiometer.

All of the sensors have some advantages over another. But for this project, Tensiometer will be excluded from further analysis because the Tensiometer just provides the reading of the soil moisture and allow user to scheduling the water supply to plant. Thus it is not suitable to interface the sensor to PLC. Another two types of sensor which is MS-100 moisture sensor and HMS 9000 Capacitive moisture sensor need further analysis because they provide good performance.

The Rain Bird MS-100 Moisture Sensor conserves water by disabling a sprinkler system from operating when the soil moisture content is high. The MS-100 Moisture Sensor uses two highly sensitive and corrosion-resistant carbon rod probes to measure true soil hydration directly at the soil level. When the soil probes detect soil saturation, the MS-100 will automatically bypass watering cycles to ensure that landscaping is never over-watered due to rain or excessive irrigation cycles. Once the moisture level drops below the user adjustable setting, the watering cycles will automatically resume.

4.3.1 Features

a) Automatically shuts off irrigation system when soil reaches user-set moisture level. Watering cycles automatically resume when moisture level is below user adjustable setting.
b) The sensor is also reliable which unlike metallic probes, the MS-100 carbon rod probes are resistant to corrosion or decay to ensure maintenance-free monitoring.

c) The benefit gain from using this type of sensor is that it prevents over watering by inhibiting watering cycles when soil has reached a desired level of moisture content from previous watering or from rain.

d) The sensor also provides adjustable rotary dial with sixteen user selected moisture set points allows unit to be used in any type of soil.

e) Integrated Bypass Switch is a special function which allows user to override the sensor. Permits manual or automatic watering to take place. This is important especially when there is a problem regarding the sensor.

f) Soil Moisture LED lights when soil reaches selected moisture level and indicates status of sensor.

g) Durable weather resistant outdoor cabinet.

h) Controls watering in just one or multiple zones.

i) Compatible with nearly all irrigation controllers on the market.

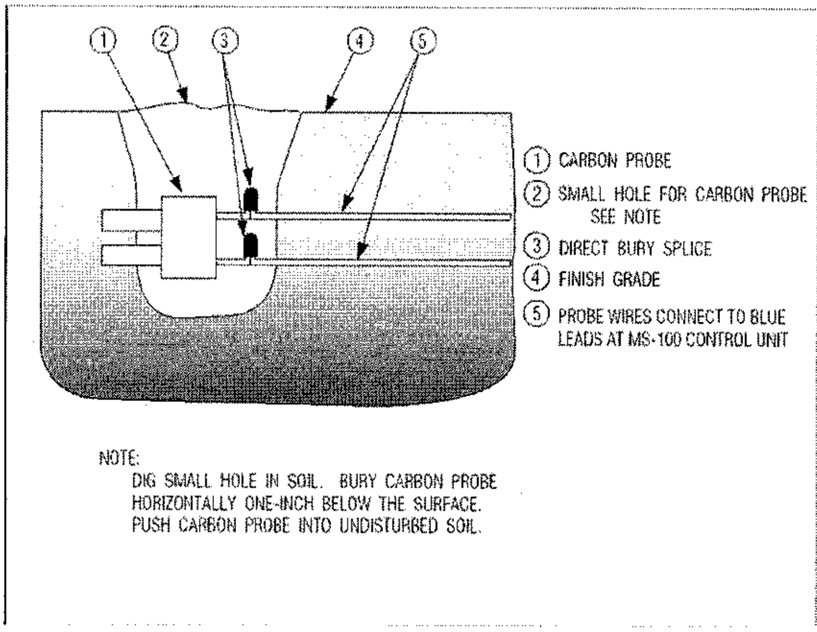


Figure 4.5: MS-100 soil moisture sensor

4.3.2 Specifications

The moisture sensor shall employ conductivity, which exists due to ionic content in water, to measure the resistance in the soil. The soil sensor shall be manufactured with two non-corrosive carbon rods for prolonged life in subterranean environments. The moisture sensor shall incorporate a provision that allows the installer to select from sixteen different moisture settings.

These sixteen settings shall be derived from comparable resistance measurements between the carbon rods of the soil sensor for varying levels of moisture content. When the moisture content increases above a user selected setting, the internal interrupt circuit shall temporarily disable the irrigation controller by creating an open circuit on the valve control signal.

Once the moisture content falls below a user selected setting, the internal interrupt circuit shall allow the irrigation controller to resume watering by restoring the valve control signal continuity.

4.4 Valve selection

	Backflow preventer	Price	Place to install
Globe / Angle	No	Expensive	Underground / vault
Anti-Siphon	Yes	Economic	6" above highest sprinkler

Table 4.4: Differences between valves

From Table 4.4, both valves are made out of PVC or brass. Valve with brass will last longer compare to the PVC which will damage due to sun heat. Each valve still needs same precautions during its operation. During its operation, dirt might get into the passage that leads to the solenoid. When there is sand or algae inside the valve, the valve may fail to open or close. Another problem is when water gets into the solenoid of the valve. These two problems need careful attention during operation of the valve.

From Table 4.4, Anti-Siphon valve was chosen in this project because it has the backflow preventer which prevent the water from flow back to its source. The valve is cheaper compared to the Globe or Angle valve.

The pressure loss in an automatic valve is the energy source used by the valve to open and close. This means that initially, during the valve is closed, the pressure is high. The high pressure will open the valve. Thus, the amount of pressure loss is needed to open the valve. Always size automatic valves based on the flow rate using the manufacturer's chart as a guide. Never assume that the valve should be of the same size as the pipe. It is very common for the valve to be a different size than the pipe it is installed on.

The size of the automatic valves is determined by the manufacturer's recommended flow range, together with the pressure loss through the valve at the selected flow. The valve manufacturer's flow chart is needed for the model of valve planned to use.

	5 GPM	**10 GPM**	**15 GPM**	**20 GPM**	**25 GPM**
3/4" Anti-Siphon Valve	5.0 PSI	5.5 PSI	6.0 PSI	8.0 PSI	---
1" Anti-Siphon Valve	2.5 PSI	3.5 PSI	3.0 PSI	4.0 PSI	9.0 PSI

Table 4.5: Pressure loss for each type of anti-siphon valve size

Table 4.5 above shows that the design flow and the pressure loss if 3 / 4" or 1" anti-siphon valve was used. For example if the design flow for this project is 20 GPM (Gallon per Minute), there will be 8.0 PSI loss for 3 / 4" anti-siphon valve but 4.0 PSI loss in 1" anti-siphon valve. For this time, the 3 / 4" was selected in the project.

4.5. Programming

The system requirement:

- The system will supply water to the plant when sensor detects soil moisture is at low level
- When start button is ON, the sensor will start to work and detects the soil moisture.
- When soil moisture is at low level, valve will open.
- Water will be supplied to the sprinkler.
- Sprinkler sprays water to the plants.
- Soil moisture sensor detects the soil moisture and gives feedback to the PLC whether irrigation still needed.
- Irrigation will stop when soil moisture is good.

The additional features of the Greenhouse:

- The roof of the Greenhouse is open when it is not raining. The roof will close when rain detector detects the rain.
- The curtain in the greenhouse is open when the temperature is not too hot. If the temperature is too hot, the curtain will automatically closed.
- The fan operation depends on the same temperature sensor. When the temperature in the Greenhouse has risen above 20°C.

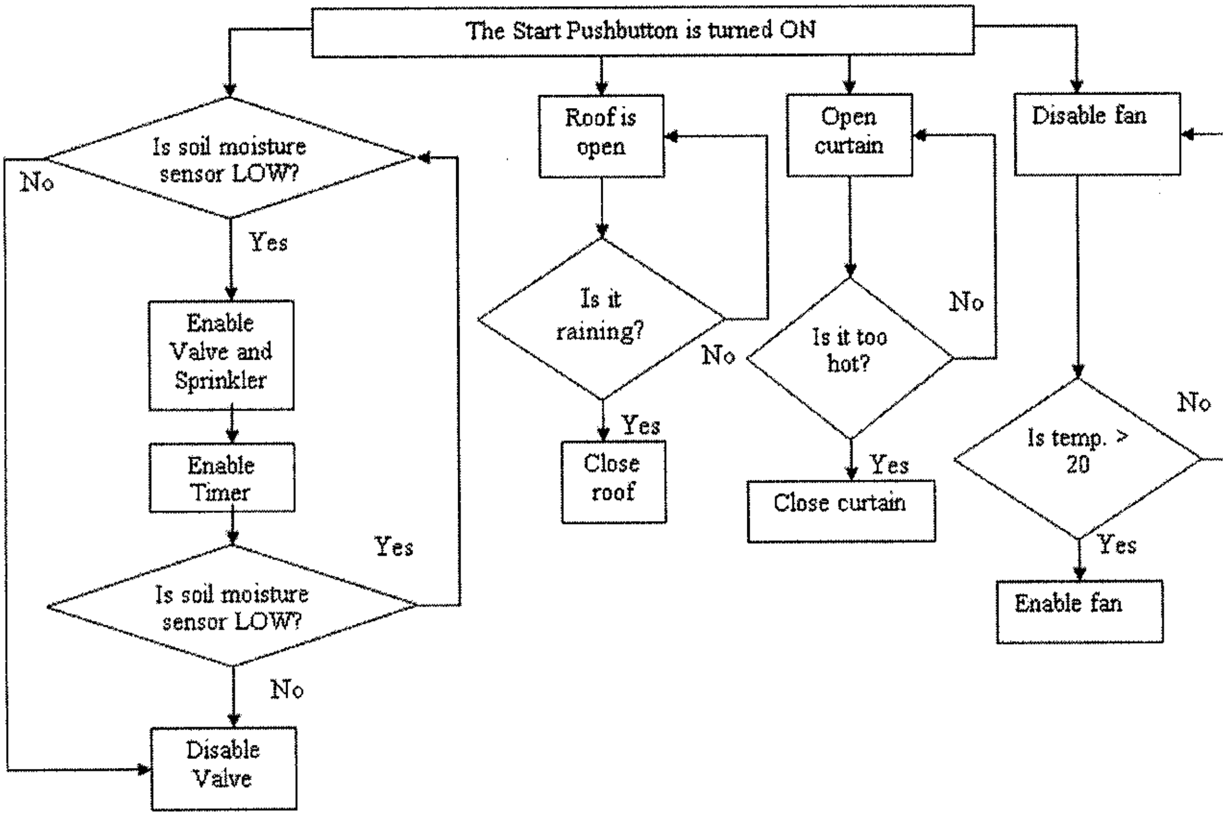
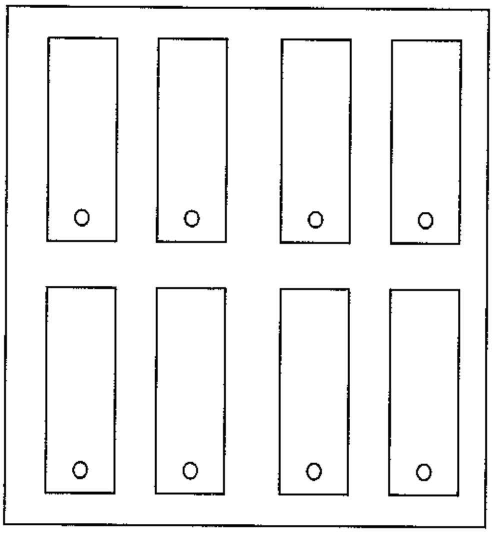


Figure 4.6: Flowchart of the system

The flowchart represented above is only for one type of flower. It is proposed that the automated water sprinkler can supply for 8 different types of flower. Because of that, 8 sensors and valves are needed. But for the prototype part, the PLC was programmed for only one type of flower to reduce the cost which is limited. The project was limited to only the automated water sprinkler design and not the whole greenhouse. The special features added in the system are temperature sensor to detect the temperature inside the Greenhouse. If it senses the temperature is high, the fan will turn ON and the curtain will close to avoid from sun heat. The rain detector would sense whether it rains or not. If it is raining, the roof will be closed.



Legend: : Flower bed

: Soil moisture sensor

Figure 4.7: Proposed location of sensors

Eight soil moisture sensors will be planted in each flower beds, because every flower beds are planted with different type of flowers. Each type of the flowers needs different amount of water. As shown in Figure 4.11, all the sensors will be connected to the input of PLC. The soil moisture sensor will warn the PLC that which flower bed has less moisture. Then, the PLC will process and give the output to the valve to supply the water. The temperature sensor will take care of the cooling system in the Greenhouse and finally the rain detector will control the opening and closing of the roof.

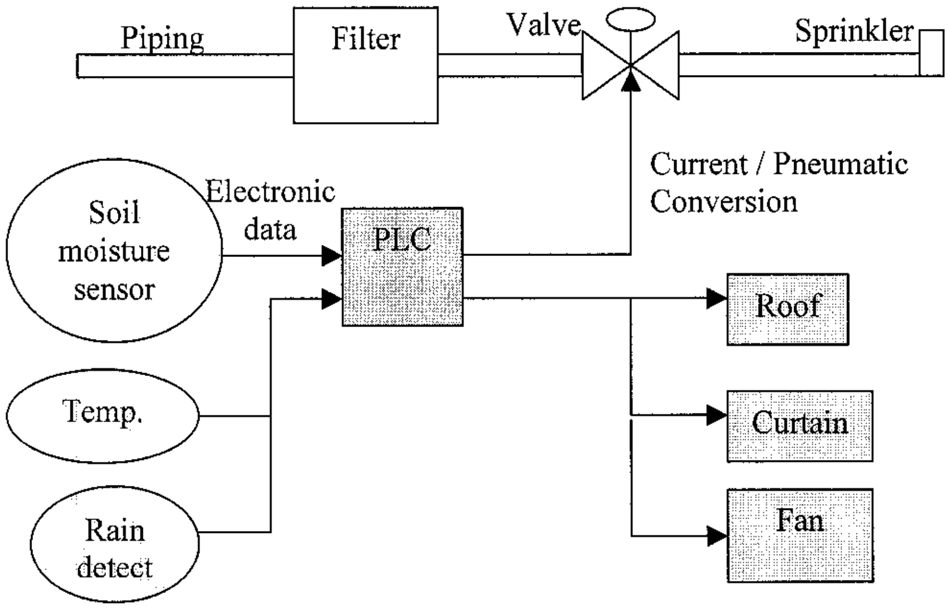


Figure 4.8: PLC and valve interfacing

By referring to the Ladder diagram provided in **Appendix A**, when the Pushbutton 1 (000) is pressed, the system is automatically ON. Pushbutton 2 (001), is used to shutdown the system (OFF). When the Pushbutton 1 is pressed, all sensors (Sensor 002 until Sensor 012) are directly connected to the PLC. Sensors 002 until 009 are specified on each flower bed which means that each flower beds contain different types of flower which need different volume of water. For example, when Sensor 002 detects that the flower bed 1 has low content of water, it will trigger the PLC. Then, water will be supplied to the flower bed 1 for the time specified by the timer (from calculation of volume of water needed by flower).Until then, the water supply will be stopped by the valve. If the sensor detects that the soil moisture is still low, the water will be supplied more until soil moisture is sufficient. The same operation is applied to each of the eight sensors (Sensor 001 until sensor 009). This means that whenever any of the soil moisture sensor sense that the flower beds are less moisture, the sensor will trigger the PLC and water is supplied to the specified bed.

For the rain detector sensor (011), whenever the sensor detects rain, it will trigger the PLC and then the PLC will close the Greenhouse's roof where the output is 1009. The output is connected to valves which supply air to single way actuators. The open and closed roof is actually to maximize the amount of sunlight enters the Greenhouse and to ensure that no rain enters the Greenhouse.

The temperature sensors (012) will sense the inner temperature of the Greenhouse. When the temperature is high enough, it will trigger the PLC and the PLC will command to close the curtain (10011). When the temperature sensor sense the temperature is greater than 20°C, the exhaust fan (1008) will turn ON.

Appendix B shows the mnemonic codes that apply to the PLC and **Appendix C** shows input and output assignment.

4.6 Sprinkler

Sprinklers are the final element to be installed in the automated water sprinkler system. There are two types of sprinklers head based on the method they used to distribute water:

a. Spray heads
b. Rotor

4.6.1 Spray heads

More properly called "fixed spray heads" these are the small heads that spray a fan-shaped pattern of water like a shower nozzle. Most use interchangeable nozzles installed on the sprinkler which determine the pattern (1/2 circle, full circle, etc.) and the radius of the water throw. Some specialty patterns are available for long, narrow areas. Spray heads are spaced up to 18 feet apart. They need between 20 and 30 PSI of water pressure to operate properly.

4.6.2 Rotor

Rotor is the term used to describe the various sprinklers which operate by rotating streams of water back and forth over the landscape. The example which most people are familiar with is the "impact" rotor sprinkler which moves back and forth firing bursts of water. The impact rotors are rapidly being replaced now by gear driven rotors which are very quiet, lower maintenance, and much smaller in size. These gear drive rotors have one or more fingers of water which move silently across the landscape. The prettiest of these are the "multi-stream rotors" where multiple streams of water rotate over the landscape one after the other. Multi-stream rotors are more expensive and much higher maintenance than the other gear drive heads. Rotors can be spaced from 18 feet to 55 feet apart. Rotors require a lot more water pressure to operate than spray heads. The water pressure at the rotor head in (PSI) must exceed the distance (feet) between the heads. For an example, if the rotors should be spaced by 35 feet apart, the pressure at the rotor should be 35 PSI.

So, for the purpose of the project, spray head was chosen because rotors are spaced farther apart and require less trenching and cost much more per sprinkler. For irrigation in greenhouse, less space needed between flowers. So the area to be watered is less than 18 feet wide. Thus the choice left was spray heads. There are 2 types of basic body styles for sprinkler:

4.6.3 Pop-up style sprinklers

Pop-up style sprinklers are installed below ground. A portion of the sprinkler rises up out of the ground when the sprinkler is operating and then retracts back below ground when not in use.

4.6.4 Shrub style sprinklers

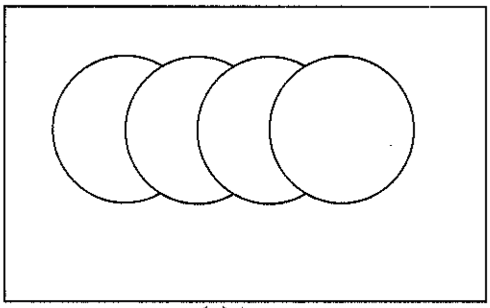
Shrub style sprinklers are installed above ground on top of a pipe called a "riser".
Either one of the basic body styles can be used for this project.

As stated above, the spray head sprinkler has been chosen to be used in this project. For this project, either pop up style sprinklers or shrub style sprinklers can be used.

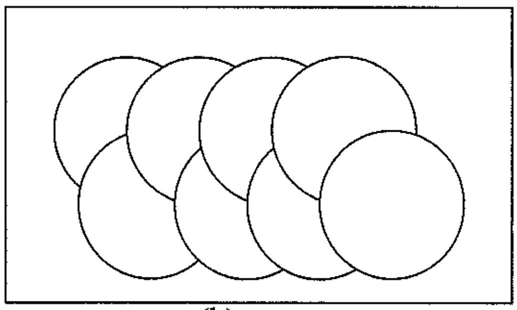
4.6.5 Sprinklers Layout

Layout of the sprinklers is important to ensure that all the flowers receive uniform amount of water. This can avoid from over watering or under watering on certain area of the flower beds.

The traditional layout for sprinkler heads is poorly suited to greenhouse watering. The standard "old style" layout is to space the sprinklers "head to head," or at spacing equal to the radius of the sprinkler throw. To provide coverage for a large area, the patterns are overlapped, as shown in Figure 4.12. Since the center of the greenhouse is naturally wetter (slower to dry), this sprinkler layout compounds the condition. Additionally, the scalloped edges of this pattern leave small dry areas where plants can suffer from under-watering.



(a)



(b)

Figure 4.9: (a) Traditional head-to-head (b) Traditional layout

One of the sprinkler products called Netafim avoids the problems of the traditional sprinkler layout. Computer modeling was used to produce a design which thousands of installations have proven to be accurate. Netafim sprinklers achieve a very high level of uniformity within a closely spaced 'strip of sprinklers'. By designing with these 'strips' laid out side-by-side, large areas can be covered uniformly. All Netafim sprinkler systems are designed with 3' spacing between the sprinklers. Thus the spacing between the sprinklers produces uniform amount of water distributed to the flowers. The layout of sprinklers was implemented for the project.

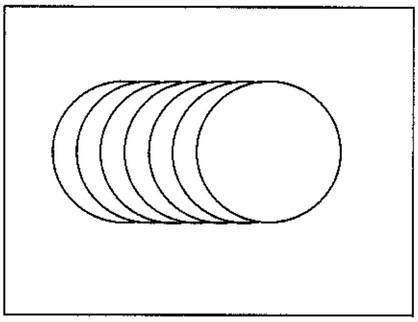


Figure 4.10: Netafim wetted strip

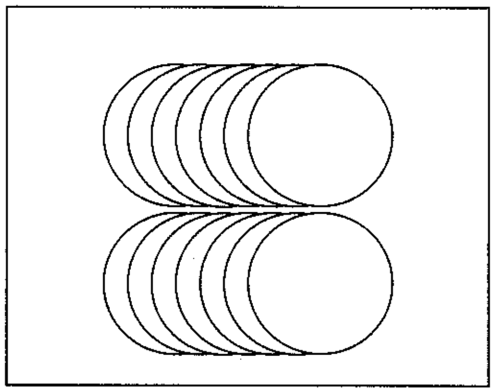


Figure 4.11: Side-by-side strip

4.7 System Modeling

Modeling the system is the most critical part to ensure the successful of the project. This is the final part which all the data from research and programming being integrated together. Modeling the system was done step by step to ensure that all parts in the prototype are working. There were 3 main parts for the prototype:

a. Input (sensors)
b. PLC (programming)
c. Output

4.7.1 Wiring and Troubleshooting Sensors

Each of these parts was tested one by one to ensure that they functions correctly. Thus, all the sensors were tested for the first part in the modeling the prototype until all of them works properly as required. As stated earlier, there are 3 types of sensor used in the prototype:

a. Water detector sensor
b. Heat temperature sensor
c. Rain detector

Below is the water detector sensor which detects whether the soil contains water or not. The sensor use 9VDC supply which will be withdrawn from the PLC. The pad (Figure 4.15) is the main part of the sensor to detect the presence of water. When amount of water in the soil is enough, then the LED, L1 will ON. If there is no water in the soil, the LED will OFF and sends the signal to the PLC asking for the valve to open and supply water to the plants. When amount of water is enough, the pad sense and sends the signal to PLC to stop watering.

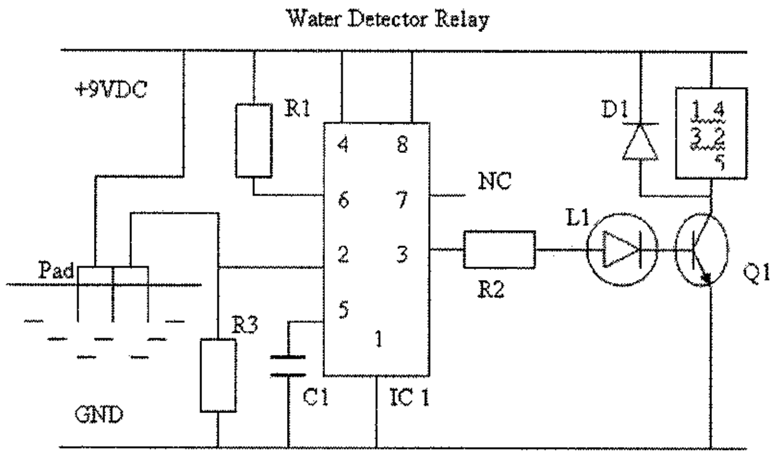


Figure 4.12: Water detector relay

The heat sensors will be used for opening or closing the curtain and ON or OFF the fan. As for water detector, the circuit also used 9VDC supply. The sensor part is called NTC (Figure 4.16) which will detect heat. Then, the signal will be amplified through amplifier (IC 1). The amplified signal from IC 1 will be transferred to the timer (IC 2) and the output of pin 3 and 1 will be connected to the PLC. This will tell the PLC whether to ON or OFF the fan. Same procedures apply for opening or closing the curtain.

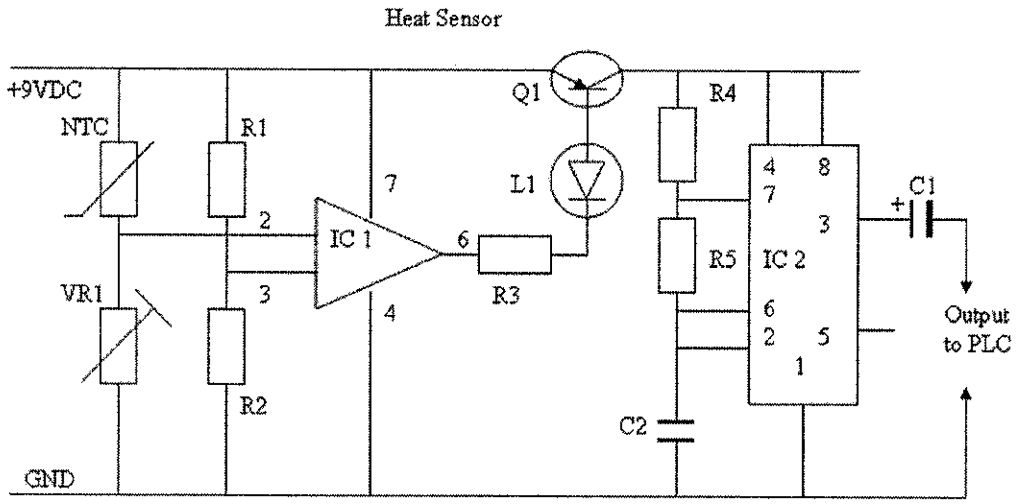


Figure 4.13: Heat Sensor

The rain detector also uses 9VDC supply. The sensor also use pad to detect the rain. When the pad sense water on the pad, the circuit is complete and this will send the signal to the PLC to close the roof. If there is no rain, the circuit is not completed (open) so, the roof will open.

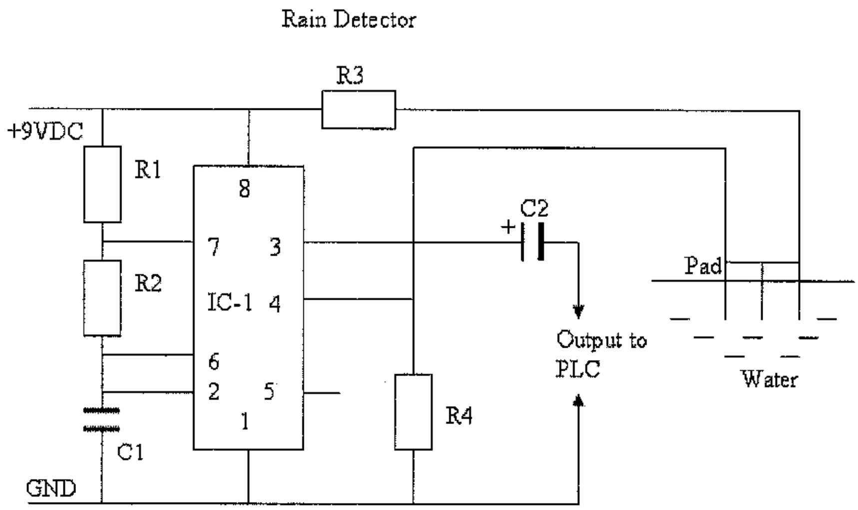


Figure 4.14: Rain detector

4.7.2 Wiring Diagram

Wiring diagram is very important in order to establish correct integration and good connection between the sensors, PLC and the output. The sensors to be used in the prototype need 9VDC voltage to operate.

Sensors were numbered as S1, S2, S3 and S4. These sensors were connected to a port and the port function is to provide connection between PLC and the sensors. Signals from the sensors will be sent to the port which will triggered the PLC and finally work as commanded or programmed by the programmer.

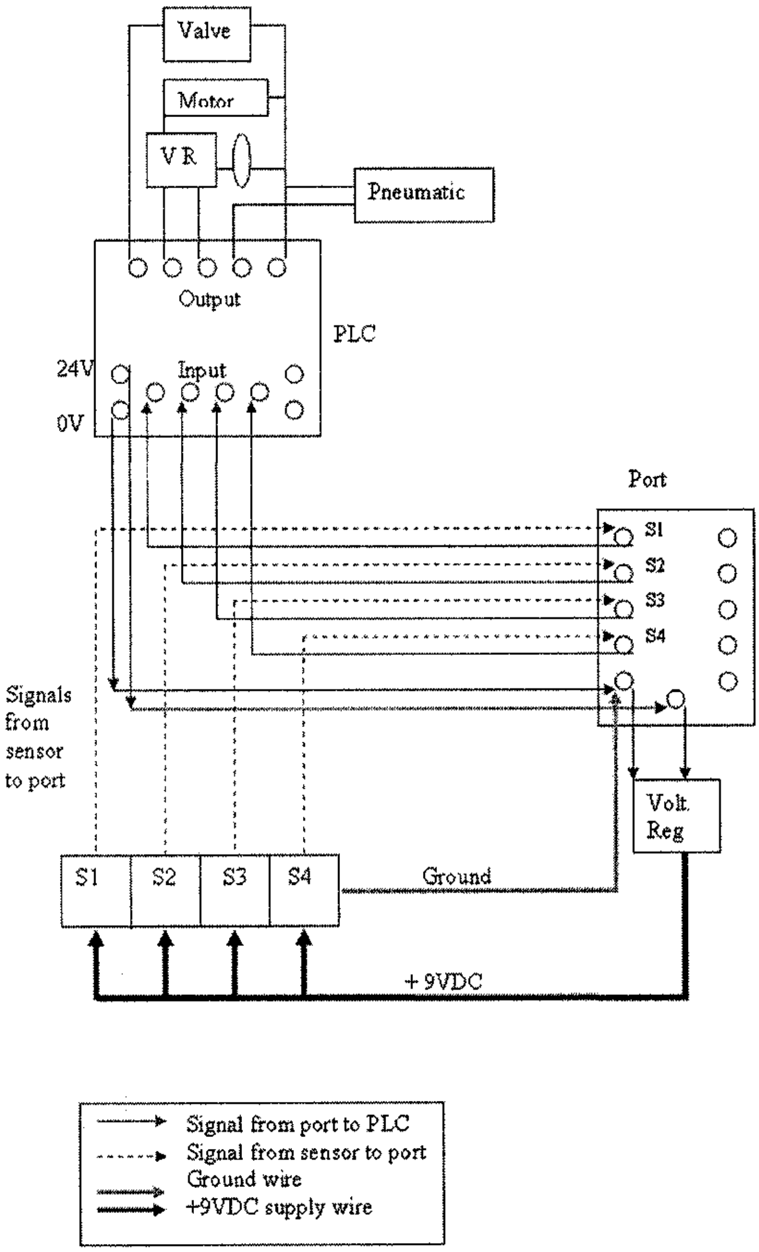


Figure 4.15: Wiring diagram

4.7.3 Test Connection between Sensors and PLC

The results of testing connection between the sensors and PLC are shown in Table 4.6:

Sensor / Test	Water detector	Heat detector	Rain detector
1	F	F	F
2	F	F	P
3	P	P	P

Table 4.6: Connection test result

For the first test, the results of connections failed to connect sensors and PLC. For the second test, only rain detector has passed the connection. The rain detector passed because it has a relay to trigger the output of the sensor to the PLC. Thus, the other sensors also needed to connect to the relay to trigger the PLC. The relay needed is 6V relay because the outputs of the sensors are in the range of 5V – 6V.

4.7.4 Implement H-Bridge Circuit for Motor

A motor is needed for opening and closing the curtain inside the Greenhouse. Thus, for the prototype, a 5V DC motor has been chosen. The H-Bridge circuit for the motor has been designed to ensure that the motor can run efficiently.

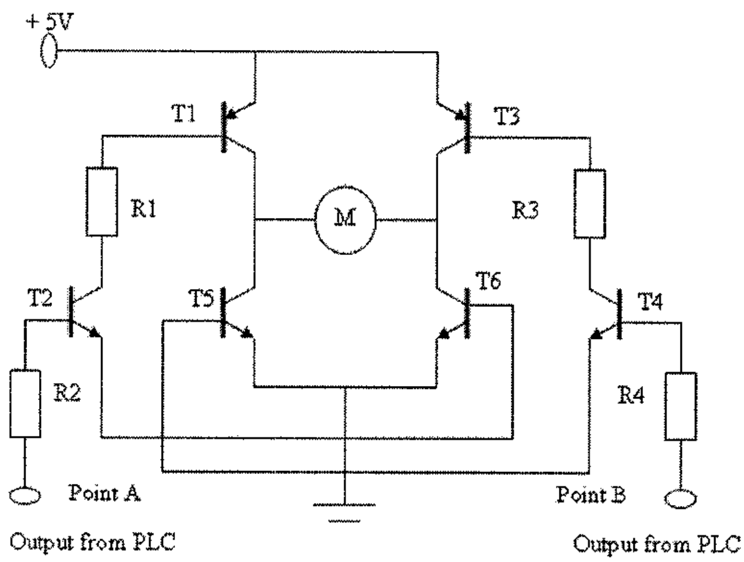


Figure 4.16: H-Bridge circuit for DC motor

Figure 4.19 shows the H-Bridge circuit needed to run the 5V motor. There are 4 NPN transistor and 2 PNP transistor needed to run the motor clockwise and counter clockwise. +5V is supplied to both PNP transistor. This will energize both transistors. Next, the transistors needed their base to be energized before the motor can operate. The command on which direction the motor should run depends on the output from PLC. The output from PLC has been marked as Point A and Point B. When the output from the PLC energized the Point A, which is the base of the Transistor 2 (T2), The T2 will ON and it will energized T6. Thus, all 3 transistors, T1, T2 and T6 are in the ON state thus the motor will flow in clockwise direction. To run the motor in counter clockwise direction, the output from PLC must energize the base of Transistor T4. T4 will be ON state and it will energize the T3. Thus, all the T3, T4 and T6 will ON and the motor runs in counter clockwise direction.

The output of the PLC is 24VDC, thus it must be stepped down to 5V before feed into the motor. Listed below are the components needed to complete the circuit:

- 2 BC 327 (PNP)
- 4 BC 327 (NPN)
- 2 resistor 100Ω
- 2 resistor 1kΩ
- 5V dc motor

4.7.5 Design a Greenhouse

A greenhouse for the purpose of showing how the inputs and outputs work has been designed. Actually, in this project only the system has to be designed but the greenhouse is to show how the process of the system works.

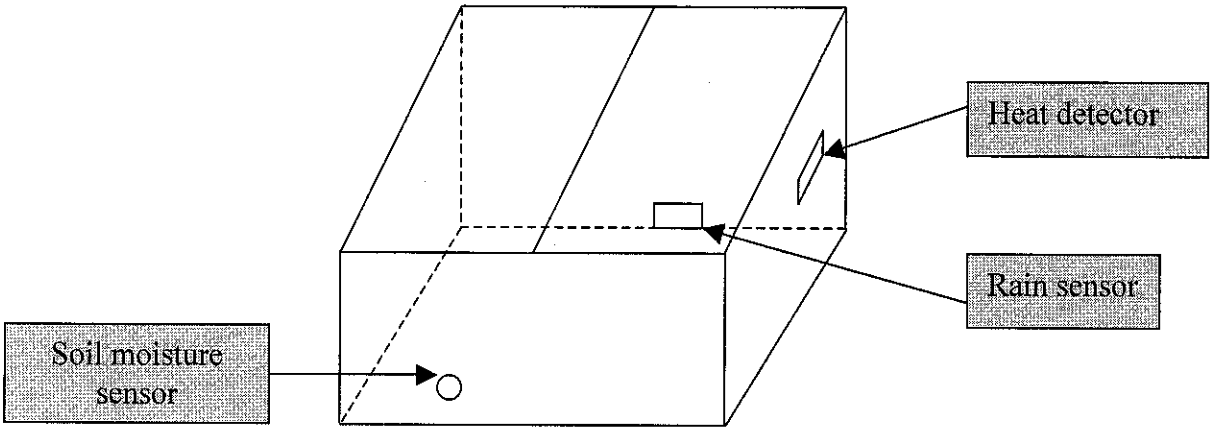


Figure 4.17: Designed greenhouse with placement of sensors

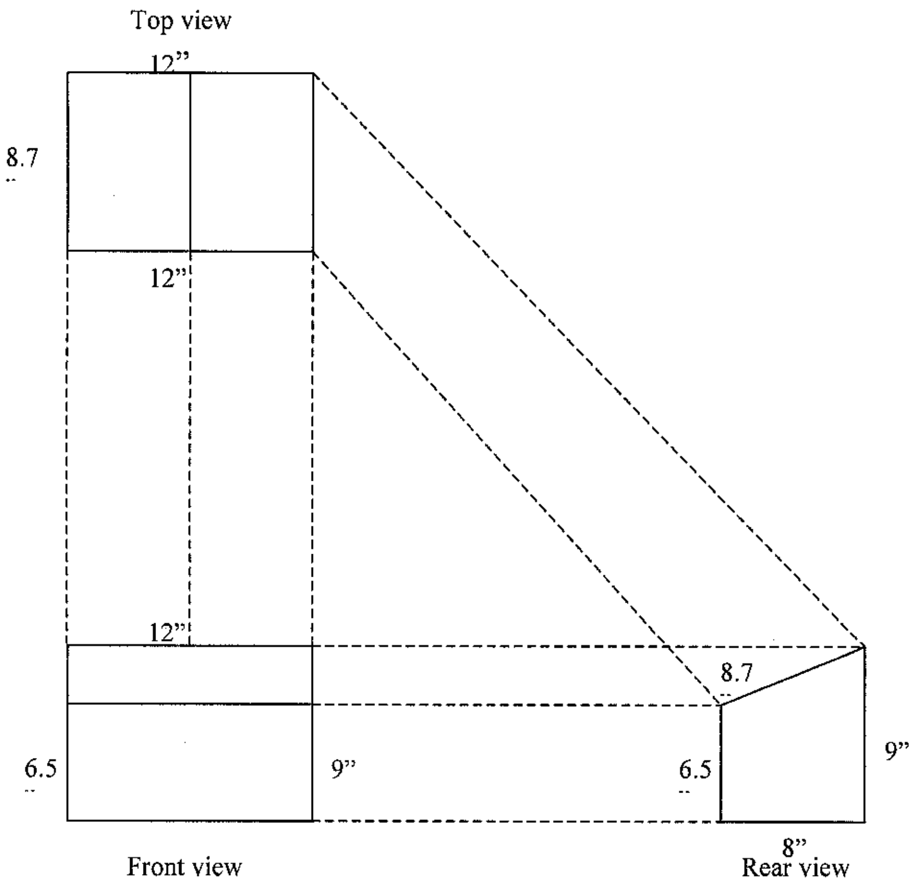


Figure 4.18: Greenhouse on different view

The design of greenhouse is shown in Figure 17 and the drawing with measurement is shown in Figure 18. The material used to build the greenhouse is Perspex. The base of greenhouse is 12" x 6.5". The rear looks like a trapezium which for a surface, the measurement is 9" x 6.5" x 8" x 8.7". At the back of the greenhouse, the surface is 12" x 9" whereas front surface is 12" x 6.5". Top of the greenhouse is the roof which the measurement is 12" x 8.7".

4.8 Cost Estimation

Cost estimation for the whole system is listed below:

Cost estimation			
Item	Quantity	Cost (per unit)	Total cost
PLC (CQM1H)	1	RM 300	RM 600
Rain sensor	1	RM 13.00	RM 13.00
Heat detector	2	RM 26.00	RM 52.00
Soil moisture sensor	8	RM 50.00	RM 400.00
Solenoid valve (3/4")	8	RM 40.00	RM 320.00
Actuators	2	RM 50.00	RM 100.00
Fan	2	RM 55.00	RM 110.00
Motor	1	RM 40.00	RM 40.00
Total			RM 1635

Table 4.7: Cost estimation

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In conclusion, some of the parts have been selected to be used in this project and some of it needs further evaluation to ensure its effectiveness and efficiency before implementing it on the automated water sprinkler system. The programming part of the system has been established and tested. From the simulation result, the program is correct and no error found. Method and calculation of volume of water needed for several types of flowers has been evaluated and it can be used for this project. All the sensors for the prototype have been carefully tested and they work. An H-Bridge circuit to run a motor has been designed and it worked properly. A greenhouse and the placement of all the sensors and outputs have been designed to show how the whole process of the system works.

5.2. Recommendation

The parts of the system such as sensor and valve have been evaluated and selected based on the specification needed for this project. The program of automated water sprinkler for greenhouse is still under progress and any problem related to the program need to be verified quickly. If the program does not work, changes have to be made before implementing the prototyping. Although it is known that during prototyping, there might be some troubleshooting regarding interfacing those part together, thus ensuring the workable program seems very important. So, by implementing all recommended above, the objective of the project can be obtained.

In the future, a study to expand the system can be made. For example, in order to centralize 3 greenhouses, a single efficient system is needed. Thus, a study for the system expansion is important for centralizing several greenhouses. It will be very economical by centralizing the greenhouses into one system.

Another requirement can be added in the system which is lighting during night. This will maximize the photosynthesis process for the flowers thus increase the amount of flowers per year. The lamps can be interfaced to the PLC.

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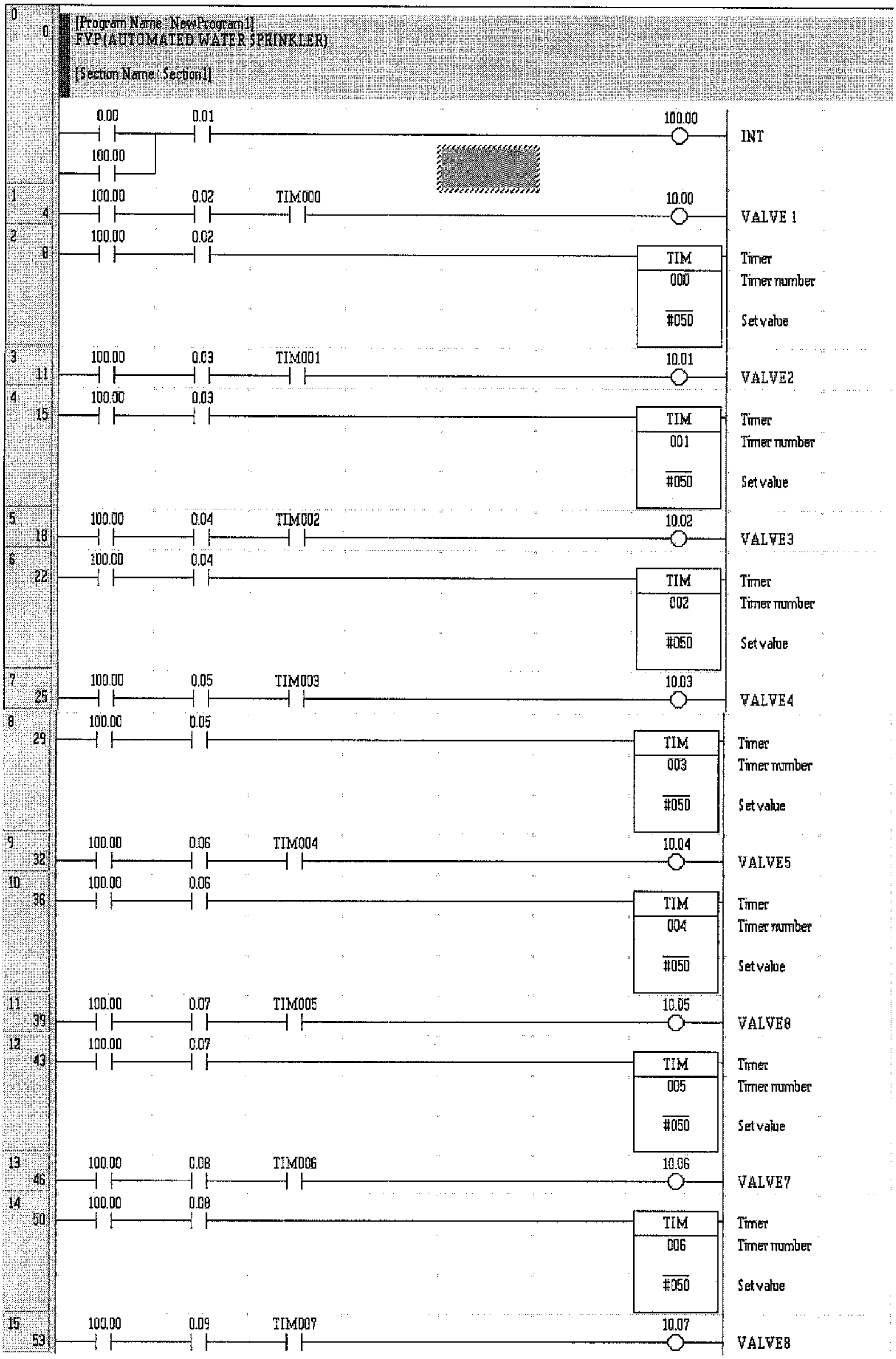
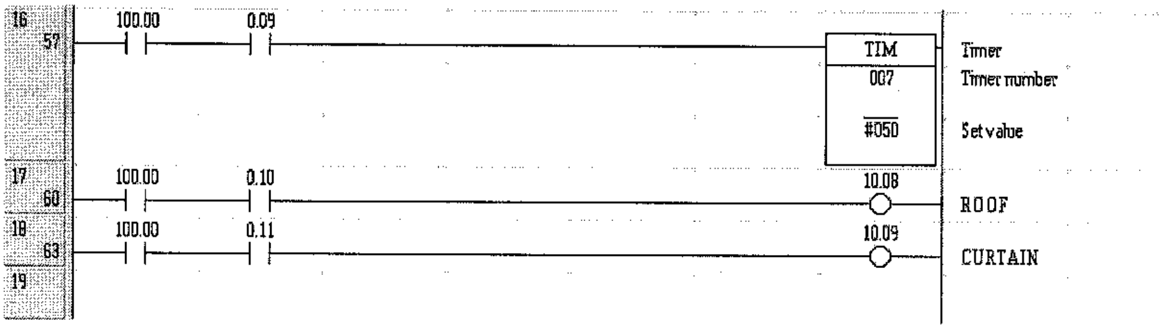
4. www.actahort.org
5. www.preciseirrigation.co.uk
6. www.rainbird.com
7. www.kjc.gov.my

APPENDIX

APPENDIX A: Ladder Diagram




16
57
100.00
0.09
TIM
007
#050
Timer
Timer number
Set value
17
60
100.00
0.10
10.08
ROOF
18
63
100.00
0.11
10.09
CURTAIN
19

APPENDIX B: Mnemonic Codes

0	0	LD	0.00	START
1	1	LD	0.00	START
	2	OR	100.00	INT
	3	AND	0.01	STOP
	4	OUT	100.00	INT
2	5	LD	100.00	INT
	6	AND	0.02	SENSOR1
	7	AND	TIM000	
	8	OUT	10.00	VALVE 1
3	9	LD	100.00	INT
	10	AND	0.02	SENSOR1
	11	TIM	000	
			#050	
4	12	LD	100.00	INT
	13	AND	0.03	SENSOR3
	14	AND	TIM001	
	15	OUT	10.01	VALVE2
5	16	LD	100.00	INT
	17	AND	0.03	SENSOR3
	18	TIM	001	
			#050	
6	19	LD	100.00	INT
	20	AND	0.04	SENSOR3
	21	AND	TIM002	
	22	OUT	10.02	VALVE3
7	23	LD	100.00	INT
	24	AND	0.04	SENSOR3
	25	TIM	002	
			#050	
8	. 26	LD	100.00	INT
	27	AND	0.05	SENSOR4
	28	AND	TIM003	
	29	OUT	10.03	VALVE4
9	30	LD	100.00	INT
	31	AND	0.05	SENSOR4
	32	TIM	003	
			#050	
10	33	LD	100.00	INT
	34	AND	0.06	SENSOR5
	35	AND	TIM004	
	36	OUT	10.04	VALVES5
11	37	LD	100.00	INT
	38	AND	0.06	SENSOR5
	39	TIM	004	
			#050	
12	40	LD	100.00	INT
	41	AND	0.07	SENSOR6
	42	AND	TIM005	
	43	OUT	10.05	VALVE6
13	44	LD	100.00	INT
	45	AND	0.07	SENSOR6
	46	TIM	005	
			#050	
14	47	LD	100.00	INT
	48	AND	0.08	SENSOR7
	49	AND	TIM006	
	50	OUT	10.06	VALVE7
15	51	LD	100.00	INT
	52	AND	0.08	SENSOR7
	53	TIM	006	
			#050	
16	54	LD	100.00	INT
	55	AND	0.09	SENSOR8
	56	AND	TIM007	
	57	OUT	10.07	VALVE8
17	58	LD	100.00	INT
	59	AND	0.09	SENSOR8
	60	TIM	007	
			#050	
18	61	LD	100.00	INT
	62	AND	0.10	RAIN DETECTOR
	63	OUT	10.08	ROOF
19	64	LD	100.00	INT
	65	AND	0.11	TEMP
	66	OUT	10.09	CURTAIN

APPENDIX C: Input / Output Assignment

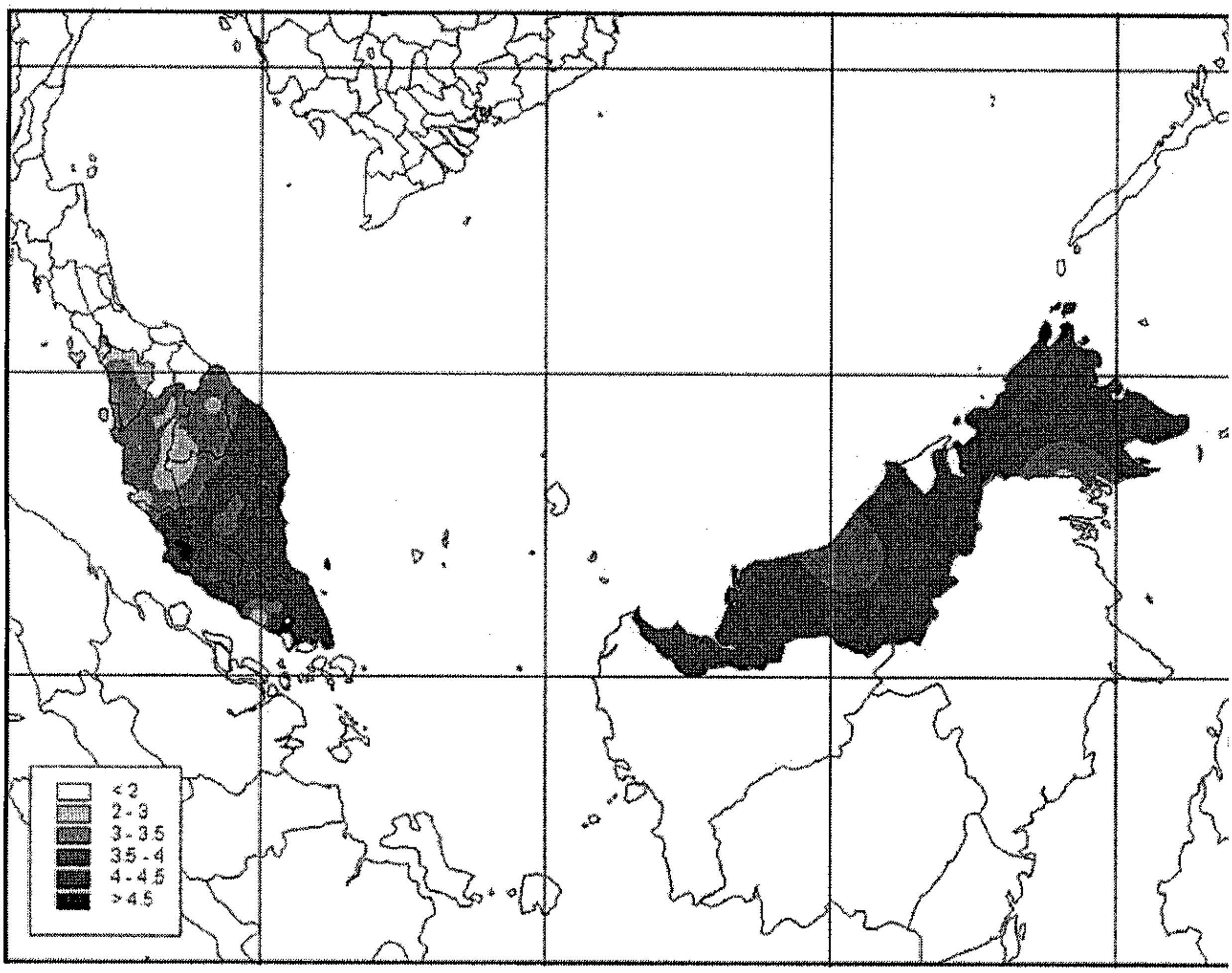
Input / Output Assignments

Input	Device
000	Push button 1
001	Push button 2
002	Sensor 1
003	Sensor 2
004	Sensor 3
005	Sensor 4
006	Sensor 5
007	Sensor 6
008	Sensor 7
009	Sensor 8
010	Heat detector
011	Rain sensor
012	Heat detector

Output	Device
10000	Valve 1
10001	Valve 2
10002	Valve 3
10003	Valve 4
10004	Valve 5
10005	Valve 6
10006	Valve 7
10007	Valve 8
10008	Fan
10009	Roof
10010	Roof
10011	Curtain
10012	Curtain

APPENDIX D: Mean Daily Evaporation Rate

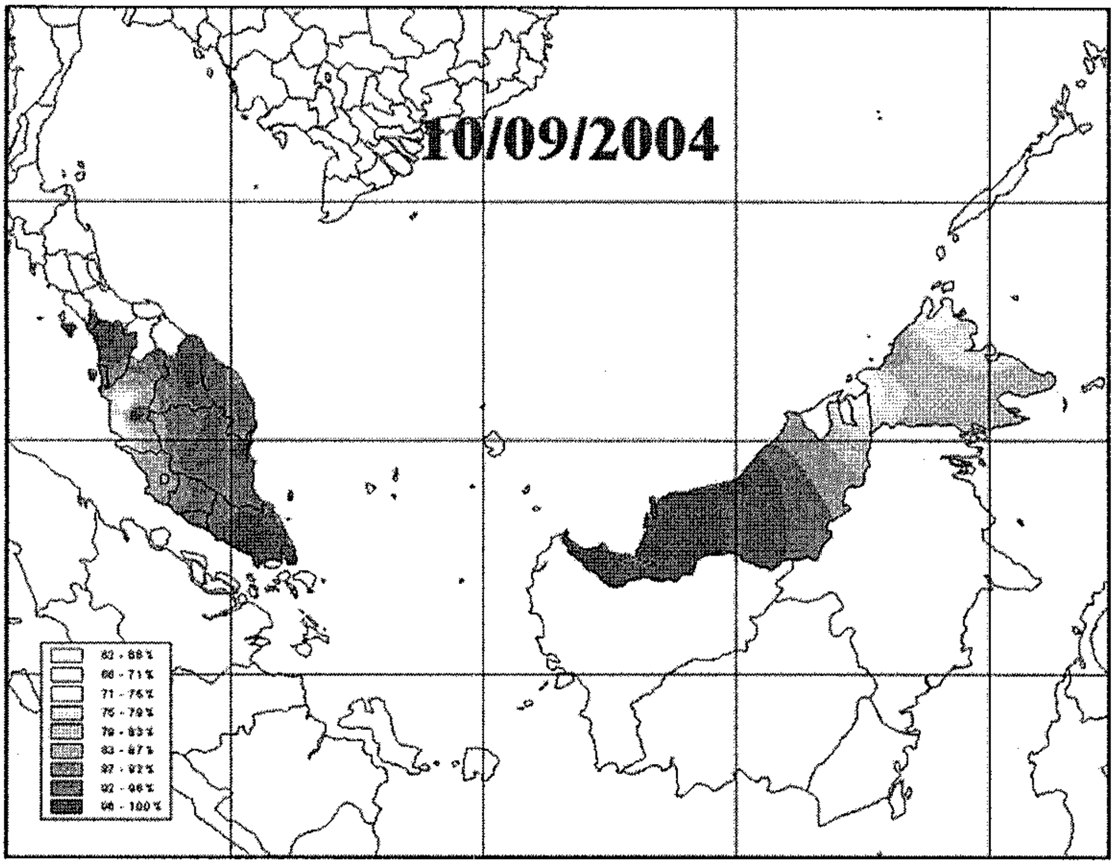
Mean daily evaporation rate in Malaysia measured in mm. The light color shows low evaporation rate. High evaporation rate is shown by red color to darkest ranging from 3.5mm to more than 4.5mm



APPENDIX E: Soil Moisture Distribution

The Soil Moisture Distribution Map displays the daily distribution of soil moisture in Malaysia on 10th September 2004. Generally, the whole Malaysia experienced very wet condition during the day with soil moisture content of the day was more than 35% per day. The soil moisture shown in the map is indicative values of the amounts of water in the top 1m depth of a horizontal soil. They are estimated daily by the water budgeting/balance method. Daily rainfall amounts are used as inputs to the soil water content. Rainfalls are measured at principal meteorological stations of the Malaysian Meteorological Service (MMS) located throughout the country. A few stations that are manned by non-MMS staff are also included to improve the spatial coverage. The holding capacity of the soil is assumed to be 30 cm out of the 1 m depth of soil. The field capacity and wilting point are assumed to have the values 0.3 and 0.1 respectively. For interpreting these maps, please refer to the following table:

Soil Moisture Content	Condition
> 30%	Very Wet
25 - 30%	Wet
20 - 25%	Moderate
15 - 20%	Dry
<15%	Very Dry



APPENDIX F: Rainfall in Malaysia

During this first decade of October 2004, normal to above normal rainfall was recorded over most places in Malaysia. However there were some parts over southeast Pahang, northeast Johore and north Sabah which experienced much above normal rainfall while some areas of southern Perak, part of west & central Sarawak had below normal rainfall. These were shown on map below. The Map of Rainfall Total (mm) shown below indicates that most parts of Malaysia were wet with rainfall amount recorded ranging from 50 to 200mm. Most parts of the west coast states of the Peninsula (west to south Perak, northern parts of Selangor and west to south of coastal Johore) together with parts of central Sarawak experienced rainfall of less than 50mm. The highest total rainfall of 250mm was recorded at Kota Kinabalu in Sabah where 7 out of 10-day period were raining. On the average, most places in Malaysia recorded 4 to 8 of raindays. In the other areas recorded between 2 to 3 of raindays while in wetter areas recorded 7 to 10 of raindays.