Fuzzy Logic Implementation for MCU on Power Savings and Efficient Irrigation System (MPSEIS) for Smart Farming

Francisco B. Culibrina and Elmer P. Dadios

Abstract—**Motor speed controller is essential to utilize and maximize the available power. In this paper, the researchers present a self-learning controller for motor speed to be utilize on Three Phase Motor using Variable Frequency Driver (VFD) for irrigation system of Smart Farming using fuzzy logic algorithm developed inside a Micro-Control Unit (MCU) environment or MCU on Power Savings and Efficient Irrigation System (MPSEIS). Motor speed can be reduced and increased using three fuzzy inputs namely, starting process, maintaining process, and stopping process. These fuzzy inputs can be triggered from feedback data of water reservoir level sensor, plant water requirements, and power optimization control. To test the controller's performance, different frequencies using variable frequency driver (VFD) in real time undergoing different water level and power load variations. The whole system is powered by photovoltaic cells, water demand on crops can be quickly and accurately calculated which can be scientific basis for water and power savings for irrigation. For continuous plant production on Smart Farm with independent power supply, new technologies using fuzzy logic were used. The results of experiment showed that the developed controller is reliable, accurate and robust.**

Keywords—**Fuzzy logic, Irrigation System, MCU, motor speed control, Smart Farm, Three phase motor**

1. Introduction

FOOD security is one of major problems that the world faces today. The effect of global warming coupled with the world population explosion poses a big challenge to solve this issue. The Philippines being a developing country suffered a lot due to lack of food security due to unpredictable weather conditions that destroyed its agricultural products. In addition, due to climate change, the Philippines power/energy generation is compromised that resulted in crops water irrigation problem. As a result, decreasing of agricultural products such as rice, corn, tomato, etc. was sentient by the farmers especially during off-season.

Next crop to rice and corn farming system is tomato, due to continued high demand in the market and increase in consumers. This was considered as one of the most cultivated vegetables having different varieties around the globe [HYPERLINK \l "Pat15" 1]. It has various uses and is attractive to consumers for its health benefits, and it is used as a siding in food presentations and preparations. It is also an important raw material in manufacturing of tomato paste.

From the record of Bureau of Agricultural Statistics (BAS)2] of the Philippines, tomato production increased in 2006 to 2010 from 188.8 thousand Metric Tons (MT) to 204.3 thousand MT which results to an annual growth of 3.87 percent. Increase of area harvested from 17.1 thousand hectares to 17.7 thousand hectares, produced an average yield of 3.08 percent, which grew from 10.26 MT to 11.57 MT per hectares from 2006 to 2010. In 2010, Ilocos is the leading region in production of tomato producing 69.62 thousand MT that contributed about 34 percent of the country's total production. Next is Northern Mindanao contributing 25 percent, followed by Central Luzon and Cavite, Laguna, Batangas, Rizal and Quezon (CALABARZON) region with 10 percent and 9 percent, respectively.

According to World Processing Tomato Council, Figure 1 shows the statistic data of global production and consumption of tomato. It shows that NAFTA, Eu-10, Eu-15, and other parts of Europe has a huge consumption compare with the production. One of the best solutions to address this problem of increasing the demand of tomatoes is an all season crop production. Smart farming

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or precision farming addresses all season plants/crops production. The focus of smart farming is to use new technology for continuous site-specific plant production [HYPERLINK \l "Mig121" 3]. The continuous monitoring of plant growth is complex and technically challenging. Thus, using fuzzy logic for this new technology, intelligence learning for power saving and efficient irrigation is utilize.

In Smart Farming, the parameters to be monitor are: soil moisture, humidity, temperature and physical appearance of the plants[4].

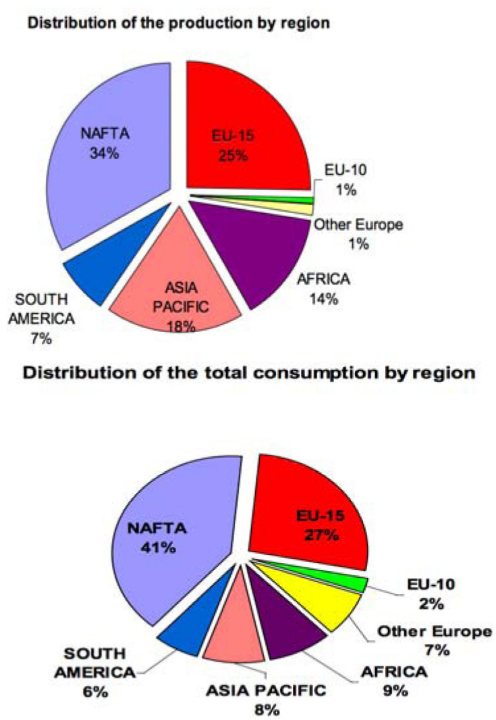

Fig. 1. Global Statistic Data for the Distribution of Tomato Production and Consumption

II. Controller Units for Power Savings and Efficient Irrigation System (MPSEIS)

A. Irrigation System

Deep irrigation must be appropriate for tomato and it requires semi-regular rather than light, daily irrigation. One to two inches of soil moisture or one gallon of water each week are the basic requirements of each tomato plants, but more accurately one gallon of water for five days. Infrequent or irregular irrigations for tomato plant results to stress and growth development problems, including blossom end rot and cracked or split fruit [5]. To address these needs, constant water supply must be maintained in spite of limited power source.

Figure 2 shows the power source system and irrigation supply for the Smart farm.

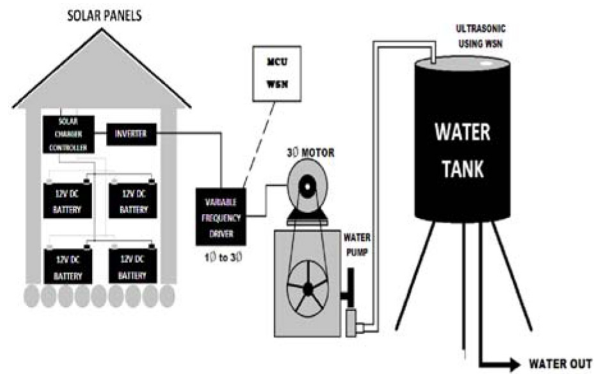

Fig. 2. Overview of Smart Farm Solar and Actuator System Using MCU,WSN, and VFD

Gravitation Cylindrical Water Tank, having a capacity of 1500 liters, was used, located at a total of 58 feet vertical altitude from the plot area. Gravitational tank was used in this research to minimize the use of energy for water pressure. The tank is required to have at least 1000 liters to maintain a minimum of 25 psi to achieve a good performance for automatic sprinkler irrigation and drip irrigation [6].

This research used wireless sensor network for each solenoid valve of drip irrigation and sprinkler irrigation system. In this study, both sprinkler and drip irrigation system shown in Figure 3 has been used. The sprinkler irrigation is used not only to water the plant but also to help lower the temperature and humidity of the plant's environment. The drip irrigation is used to increase the soil moisture content of the plant's surrounding.

Figure 4 shows the general control system for water supply and irrigation.

$$psi = 0.433 \ x \ height \ in \ feet \qquad (1)$$

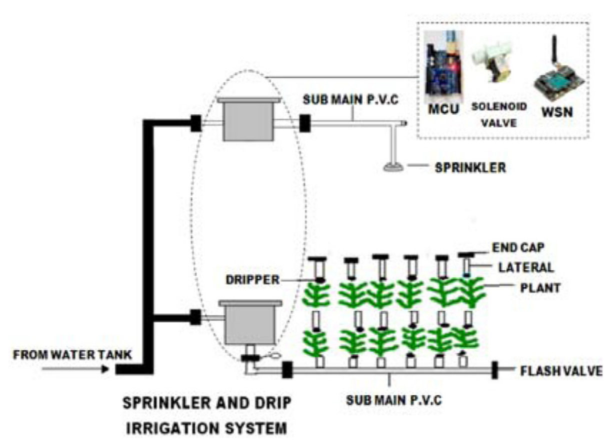

Fig. 3. Sprinkler and Drip Irrigation System with solenoid valve, MCU, and WSN

The system irrigating 500 tomatoes on the farm has a total water consumption of 100 gallons or 400 liters of water every day. The system arrived at a formula shown in equation 1 for water consumption per tomato per liter.

$$\text{Consumption(liters)} = 1\,\text{tomato} \times \left(\frac{1\,\text{gallon}}{3\,\text{days}}\right) \times \left(4\,\frac{\text{liters}}{\text{gallon}}\right) \quad (2)$$

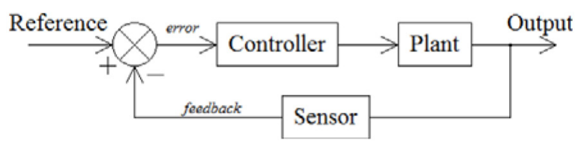

Fig. 4. General Control System

B. Power Requirement

In this paper, the system uses 1 HP three phase induction motor to pump and generate water. This is more efficient compared to a single phase induction motor [7] since the whole system is supplied by 1KW photovoltaic cell (solar panel) and 200 ampere hour storage battery. The challenge of using three phase induction motor was encountered and it was addressed by using Variable Frequency Drive (VFD) and Micro Control Unit (MCU). The MCU were programmed by implementing Fuzzy Logic Control.

1. Variable Frequency Drive (VFD)

VFD is a device used to control the AC motor speed and torque by varying its input frequency and voltage [HYPERLINK \l "Dad12" 5] [6]. The VFD is used to drive an electric motor by varying the frequency and voltage supply. To prevent high current requirements in starting up a 1 HP three phase motor, the VFD is programmed for gradual increase of frequency from 0Hz to 60Hz within 5 seconds. Since frequency are directly related to the motor speed (rpm) [HYPERLINK \l "Eng10" 7], starting-up of three phase induction motor requires only small amount of current compared to direct single phase motor. Experiment data can be seen in Figure 10.

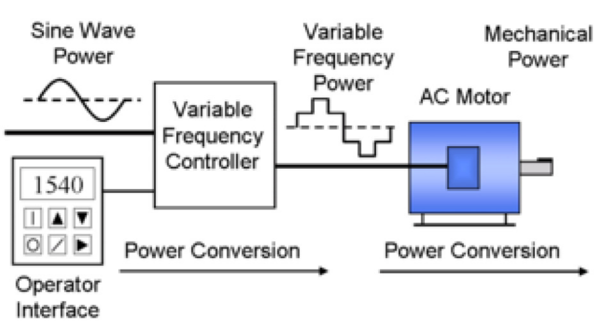

Fig. 5. Basic operation of VFD and 3 Phase Motor

2. Three Phase Induction Motor

Figure 5 shows the actual 1 HP three phase induction motor used in this research that runs on a three phase AC supply. The advantage of this setup is that the construction is simple and rugged, reliable, highly efficient, has excellent power factor, economical, and requires minimum maintenance [8].

III. PROCESSES INVOLVED IN FORMULATING THE FUZZY-MPSEIS

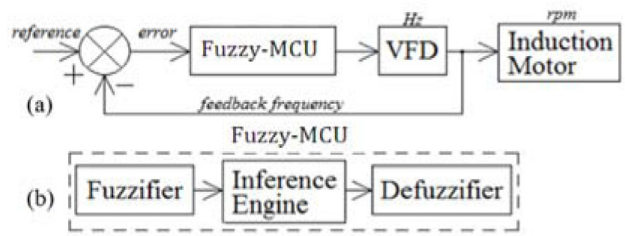

Fig. 6. Components of the fuzzy logic - MCU controller

A. The Fuzzy Logic-MCU Process Flow

The architecture of the fuzzy logic controller implemented for power savings and efficient irrigation system using a Micro-Controller Unit (MCU) can be seen in Figure 7. The starting point (SP) served as the reference value of the induction motor speed. Another input, process value (PV), is obtained as the feedback value of the variable frequency drive (VFD). SP and PV will be used to solve error and rate of error. Figure 7 shows an illustration of the fuzzy control used. In this setup, the micro-controller unit (MCU) served as the main controller where the fuzzy logic algorithm was programmed. The fuzzy control in this research consists of a fuzzifier, an inference engine, and a defuzzifier[HYPERLINK \l "Mam74" 9 , HYPERLINK \l "RLa99" 10].

B. The MCU Programming

In this study, there are two inputs and one output of the system. The inputs are the water level and energy available, and the output is the motor speed. The water level has three membership functions which are L, M, and H. L stands for low, M stands for Medium and H stands for high level. For energy available there are four membership functions which are VL, L, M, and H.

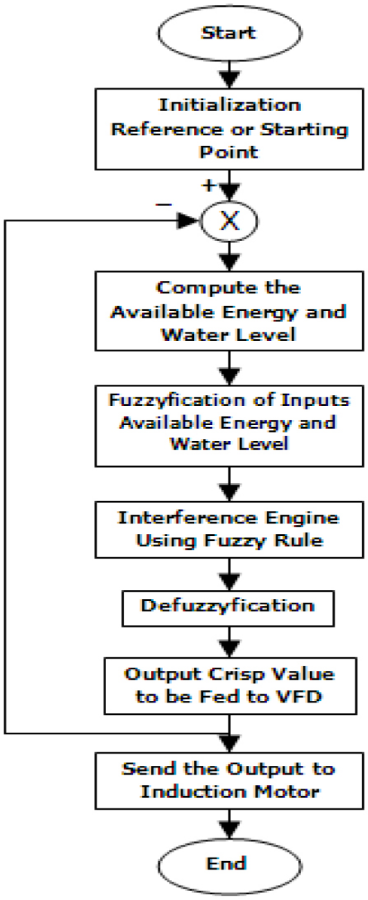

Fig. 7. Fuzzy Control Flow Chart Diagram

VL indicates for very low, L stands for low, M stands for medium and H stands for high. The output motor speed has three membership functions such as Stop for stopping, M for moderate running and H for High speed running.

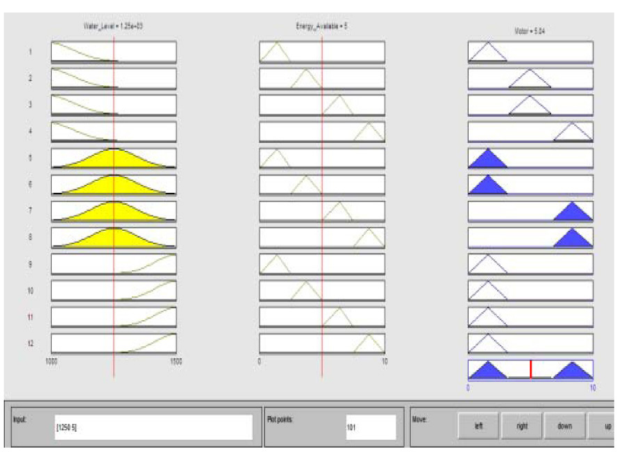

Fig. 8. Fuzzy Logic Rule and Membership Function

TABLE I
FUZZY RULE

Water Level	Available Energy	Motor Speed
L	VL	Stop
L	L	M
L	M	M
L	H	H
M	VL	Stop
M	L	Stop
M	M	H
M	H	H
H	VL	Stop
H	L	Stop
H	M	Stop
H	H	Stop

IV. EXPERIMENT RESULTS

The information given in Table 1, Figure 7 and Figure 8 were implemented in C language program. The response of motor controller is shown in Figure 9. This indicates that the energy consumed for the whole system is very minimal. *The output energy consumption for the irrigation system to fill the tank is 3.73kW-hr/day. To maintain the 1500 liters of water as mentioned earlier, the energy requirements for the system is 1.24kW-hr/day.*

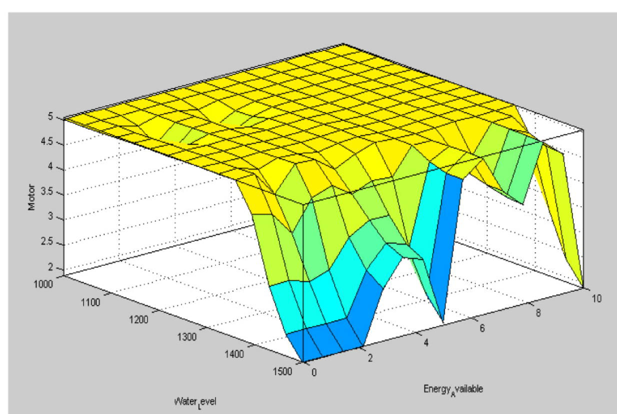

Fig. 9. Fuzzy Surface output for Water level, Energy available and Motor

V. DISCUSSIONS AND ANALYSIS OF RESULTS

Figure 10 shows the comparison of the results of the current consumption for the proposed MPSEIS against the conventional system. Note that the conventional system uses 1HP single phase induction motor. It was observed that the conventional system required high current for starting process. This also gave a very high average current consumption of 8.1 amperes. This problem was solved using three-phase induction motor with variable frequency drive (VFD) implementing the fuzzy logic controller that maximized the percent energy savings. It is possible even if the supply coming from photovoltaic cell (solar panel), the system can manipulate the starting revolution per minute (rpm) of motor by gradual increasing the frequency (Hz) from 0Hz to 60Hz induced in the motor, since the rpm of motor is directly proportional to frequency. The current requirements resulted into a very minimal value. It was also noted that the current consumption of MPSIES had an average of 2.0 amperes, while the conventional system had an average of 8.1 amperes, which can be seen on Table II. The graph also showed that the out

MPSIE are linear while conventional system are non-linear.

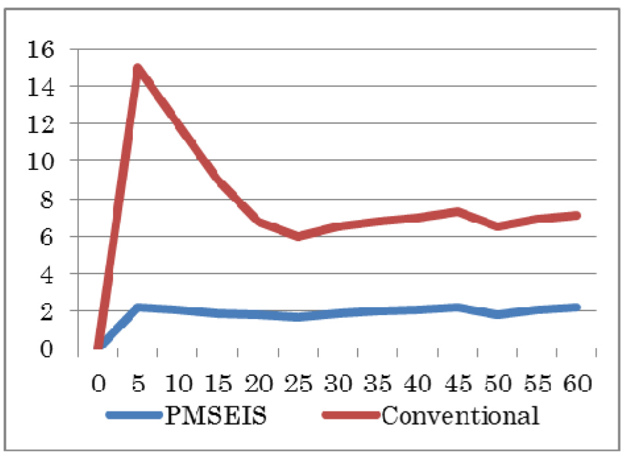

Fig. 10. Line graph of current consumption for PMSEIS and Convention

TABLE II
% Savings and Current Consumption of MPSEIS and Conventional System

Time in seconds	0	5	10	15	20	25	30	35	40	45	50	55	60
PMSEIS	0	2.2	2.1	1.9	1.8	1.7	1.9	2	2.1	2.2	1.8	2.1	2.2
Conventional	0	15	12	9	6.8	6	6.5	6.8	7	7.3	6.5	6.9	7.1
% Savings	0	85.3	82.5	78.9	73.5	71.7	70.8	70.6	70.0	69.9	72.3	69.6	69.0

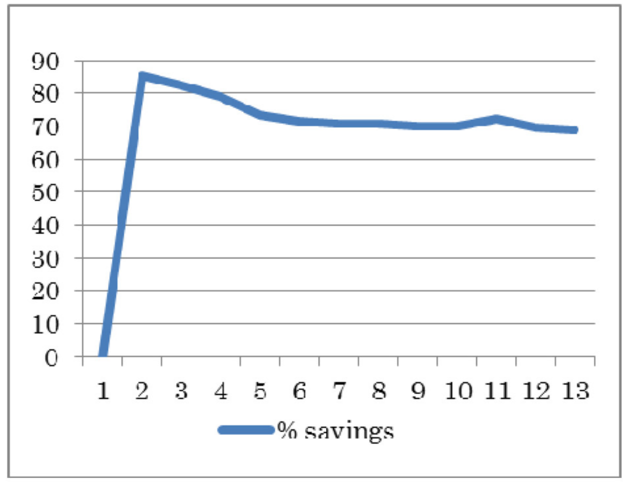

Fig. 11. Percentage Savings of Current

Figure 11 shows the percentage savings of current where calculated based on the Equation 3. The average current savings was computed equal to 73.7% compare from the conventional system.

$$\%\,\text{savings} = \frac{\text{con.current} - \text{MPSEIS Current}}{\text{Con.Current}} \times 100 \qquad (3)$$

VI. Conclusion and Recommendations

Using VFD and MCU with Fuzzy Logic-Based Motor Speed Controller into Irrigation System for Smart Farming was proven to be successful. Based on the experiment results, it is significantly better and reliable compared to the conventional controller in terms of load variations handling.

For enhancing the capabilities of MCU, fuzzy logic was appreciated for providing intelligent automation system process. The result of the developed controller showed that it is reliable, accurate and robust by providing a percentage savings of current usage which is equal to 73.7 percent.

Acknowledgements

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