The Application of Automatic Irrigation Pump System with Solar Power in Rainfed Field

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ABSTRACT— ***This study aims to generate irrigation pump system equipped with solar power control on - off automatically for rainfed. The control system device is Arduino ATmega328P microcontroller that serves as an automatic control for on-off pump with solar power. The setpoint within the microcontroller system is determined by the soil conditions in general that exist in the field, those are the on pump when the pF is 4, 1 and off when the pF is 2.1 pF. The components of the solar irrigation system consists of a solar panel, charger controller, batteries, inverter - those can operate for 24 hours. The experimental results indicate that the automatic control system using a microcontroller was able to function properly in controlling pump working with solar power, with reference pF in the land specified by setpoint. The average pump's working time (on-off) for an area of 1970 m^2 is 60-75 minutes with average debit 17.45 m^3 / min.***

Keywords— irrigation, pump, solar power, rainfed field

1. INTRODUCTION

The increasing productivity of paddy fields has been into a very popular issue. The food stability programs in order to meet the needs of the people became a concern under discussion and should be resolved shortly. There are efforts needed to increase the productivity of rice so that the regional food stability could be increased [1].

Various methods are used in order to increase food production for instance by extensification, extending the effort to increase food production to expand planting areas; diversification, diversification of cultivated plants in the landscape; and intensification, an effort to increase food production intensvely on lands that were already exists by using quality seeds, appropriate fertilizer and effective and efficient irrigation [1].

In accordance with the National Policy of Water Resources of Indonesia in 1994-2020 which emphasizes improvements in efficiency and equity of the use of surface water and groundwater in supporting the process of crop production. The obstacles in the rain fed farming is the limited amount of rainfall. Meanwhile, if rain fed irrigation cultivated with the use of the pump, the problems would come from the high operational costs, because the pump is highly dependent on fuel [1].

Technology and equipment for water pumps have been available and easy to obtain, but the fuel (gasoline) which is used as a source of propulsion pump is sometimes an obstacle, both in terms of availability and price. Cost to buy fuel on a regular basis into operational costs that must be incurred farmers, so that at certain moments dizzying farmers because it coincided with other production costs [1].

Utilization of solar power to drive the pumps is one solution to decrease operational costs to be incurred by farmers. Solar power is the most promising energy sources considering the sustainable feature and large amount. Solar power technology systems used in the pump does not require fuel so it does not require fees from the water users, operators do not need power to operate, and it has a longer lifespan [1].

Research results [1], showed the potential of solar energy in Nagari Singkarak that can be utilized to drive a water pump for irrigation. The measurement results showed, batteries with a capacity of 12 V and 100 Ah takes 4 hours for charging with 50 Wp PV panel for 5 unitsBatteries as an energy source were able to move the pump with a power of 125 Watt for 7.52 hours and average debit capable of being pumped is 17.45 liters / minute. In use, from 24 periods of planting planned on rain-fed land, there are three times planting the pump that the operating hours would be met by batteries, ie January 2, February 2, and November 2. Based on the results of the financial analysis, the three times of planting can be said financially feasible in practice, because the B / C ratio> 1 and NPV> 0.

The utilization of solar power to drive the pump is not only seen from the power source provided but it should also be noted from the availability of groundwater. The intensity of sunlight was available from morning until late afternoon, so the pump will automatically work. In afternoon when the sun rays continues to decrease until it stops (nighttime), the pump will automatically stop working. So forth every morning until afternoon the pump will work in an average of 8 hours per day. Pump's system that works like this would have an impact on the availability of groundwater.

Preservation of ground water should be maintained, because the ground water is a renewable resources. Groundwater can be discharged and damaged, then one of the solutions in the utilization of the irrigation system is the implementation of automatic pump with solar power. The working principle of automatic pump (control of on-off*)* are run by sensors which are designed according to the needs. The control system is designed based on the conditions of pF, which is between 4.1 to 2.1. In this pF condition, plants were able to absorb water from the soil. With the existence of this control system, the pump will work in accordance with the water needs of plants, so the sustainability of groundwater's availability is maintained. The goal is to produce a pump irrigation system equipped with solar power control on - off automatically for rain fed.

2. RESEARCH METHODS

Research activities include: engineering and technical testing of automatic irrigation pumps with solar power on rainfed. The working principle of a technical test is started from the collection of solar energy in solar panels. The collected solar energy is converted to DC energy by photovoltaic cells. The DC electric current is then converted into AC current by an inverter, and then used to drive the pump. The pump is equipped with automatic on-off control, where the pumps will work according to the needs. Control of on-off automatically created based on the general conditions of pF.

2.1 Research Sites

The location of the study are rainfed paddyfield in Nagari Singkarak, X Koto Singkarak District, Solok regency, West Sumatra, Indonesia.

2.2 Data and Tools

Data needed in this research included: pump specifications, batteries, solar panels, and the working hours of the pump based on the sensor settings. Data were collected through direct observation in the field. Equipment used to design automated irrigation water with solar power and technical tests are:

1. The solar panels
2. Inverter and controller
3. Water pump
4. Microcontroller

2.3 Experimental Procedure

2.3.1 Designing Sensor

The sensor acts as a control *(on* and *off)* of the pump. The sensor is designed based on the conditions of pF that is between 4.1 to 2.1. In this pF condition, plants were capable to absorb water from the soil. Once the sensor has already been drafted, then the test is done and if the sensor is not working according to function, modifying was performed. Once the sensors could be used, the sensor is connected to the pump. Flow diagram of the study are presented in Figure 1.

2.3.2 The Design and Technical Test

The determination of operational systems automatic irrigation pumps with solar power is highly dependent on the pF *(Potential Free Energy)* ground conditions. When pF pump reached 4.1, the pump will be switched *on*, and at pF 2.1 the pump will be switched off.

2.3.3 Data Analysis

Technical data analysis test of automated pumps irrigation with solar power conducted were:

a) The sensor is able to function as an on-off pump control, pF soil data is taken 5 times at the time of the pump *on* - *off*.
b) The duration of pump operation to achieve the pF conditions 2, 1 (pump *off)* on pF condition 4, 1 (pump *on)*, data is taken 5 times. The diversity of pF value when the pump *on* and *off* is calculated using the following equation:

$$S = \sqrt{\frac{\sum_{i=n}^{n}(x_i - \bar{x})^2}{n-1}} \quad \text{……//……(1)}$$

$$KV = \frac{S}{\bar{x}}\ x\ 100\ \% \quad \text{……(2)}$$

with:
X = the average length of time the pumps operate
Xi = the length of time the pump operates on the i-th measurement
S = standard deviation
KV = coefficient of the diversity of the average length of the pumps' operating time (%)

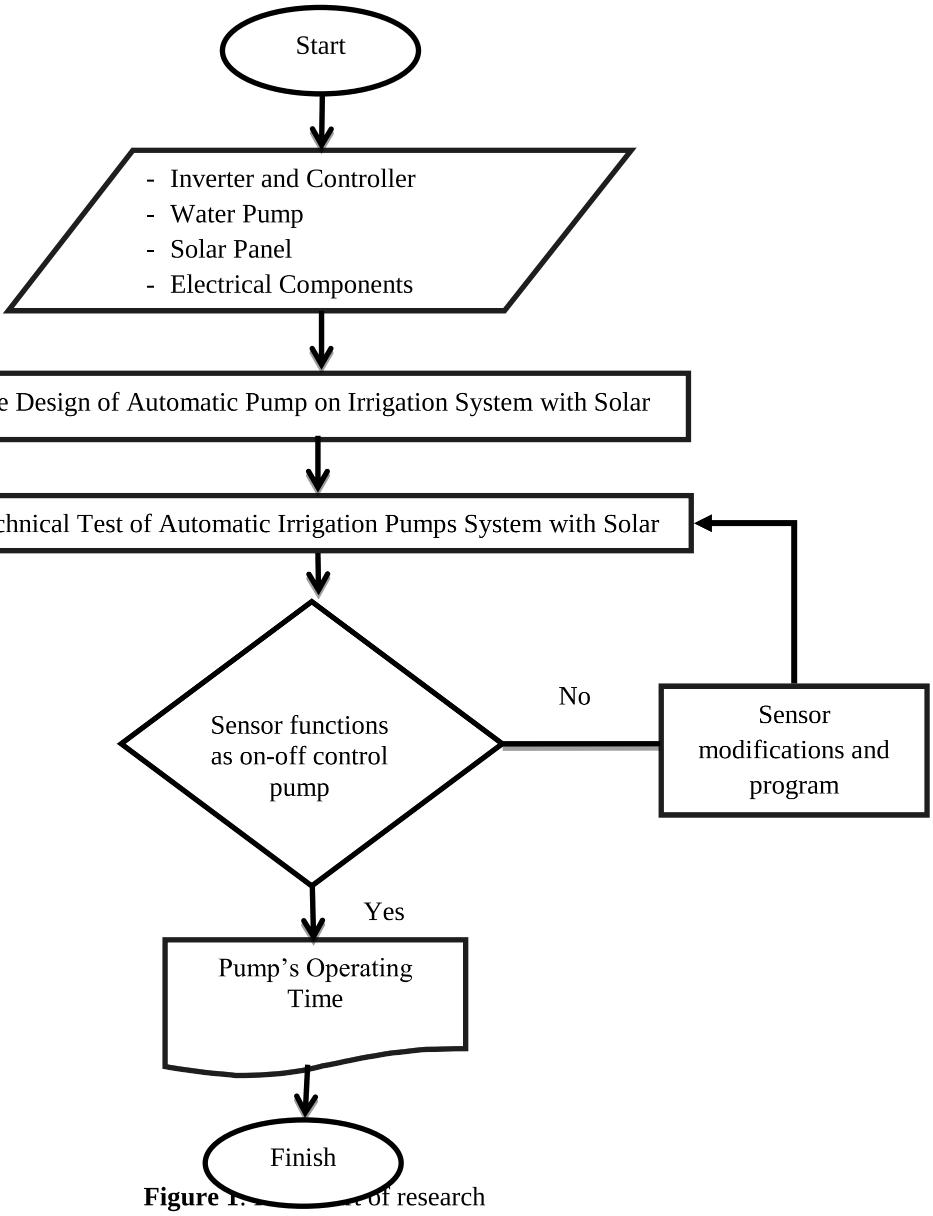

Figure 1. of research

III. RESULTS AND DISCUSSION

3.1 Land Condition Experiment

The ability of plants to absorb water is available depending on the type of plant and soil profiles that can be reached by the roots. The range of soil water available for plants is a bound water between field capacity (2.54 pF) and permanent wilting point (pF 4.2) in which amount varies depending on the texture of the soil, the finer texture, the greater the range [2]. Location of the study had clay *(clay)* texture. The data of the soil in the study are shown in Table 1.

Table 1: Nature of soil physics field trials

The nature of Soil Physics	Unit	magnitude
Texture		
Sand	%	16.30
Dust	%	18.58
wiry	%	65.12
Water content		
PF 2,54	% volume	31.47
PF 4.2	% volume	20,01
PF 2.01	% volume	43.24
Drainage Pore		
Air Available Pore	% volume	17.13
Quick Drainage Pore	% volume	15.73
Pore Drainage Slow	% volume	5.50

According to [2], ground water wasavailable to the plants ranged in soil moisture content 20-55% for clay and 8-18% for sandy soil. Furthermore [3] stated that the soil's ability to store water available is a function of soil texture and structure.

3.2 On-Off Control Irrigation Systems Solar Pump Design

3.2.1 On-Off Control System Software

On the software designing, the manufacturing and adjusting programs to perform a series of automated system testing was performed. The writing of control program was written in the Arduino Uno pages. Programming language based on the C / C ++ programming language. Generally, sotfware control set leads to *an* on-off system based on the value of land pF. The hardware circuit schematic is presented in Figure 2.

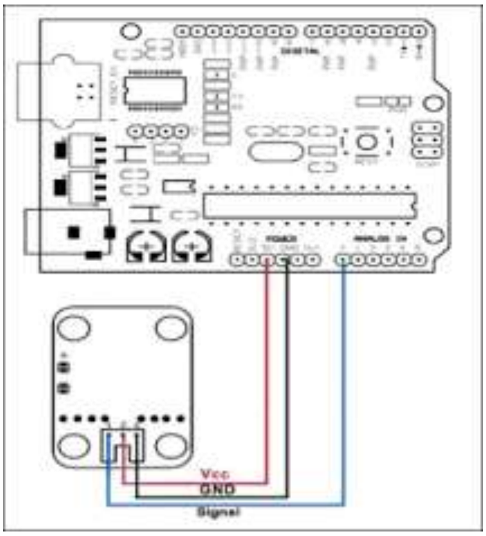

Figure 2: Schematic circuit hardware

3.2.2 On-Off Control System Hardware

Hardware design stage consisted of soil moisture sensor, Arduino UNO Uno $_{R3}$ board models microcontroller with ATmega328P IC, 12 volt adapter, relay, real time clock (RTC) module, Shield Terminal Screw and micro SD. Soil moisture sensor has 2 pieces of probe with 6 cm long, 2 cm wide, and 2 mm thick which is capable of receiving 3.3 to 5 volts with voltage value output 0 volts to 4.2 volts has 3 pins (ground, power, and input).

PF setpoint value is determined based on the ground’s pF, with the following steps:

1. Results of laboratory analysis in the form of water content for each pF (2, 0 to 1; 2.54 and 4.2), is used to find the correlation between pF and ADC. By getting the pF and ADC correlation value, correlation with water content was obtain as seen in Table 2.

2. The final values in Table 2 became *setpoint* reference to *on- o ff* censorship, while the pF is 4, 1 the pump is *o n* and the is pF 2, 1 while the pump is *o ff*.

In general, the soil conditions become wetter, the ADC value and moisture content increased while pF decreases and vice versa. Overall, the parts of the device on-off control can be seen in Figure 3.

Figure 3: Device control system

The device control system consists of several parts: the main part is the UNO microcontroller which serves as the main controller with IC process used is ATmega328P, the next *real time clock* (RTC) module which is used as a data logger equipped with micro SD. RTC module is connected to the microcontroller with a *screw terminal* connector *shield.*

Sensor components directly associated with the microcontroller, while readings displayed by the LDC 2x11. The sensor will read the conditions of the soil pF after receiving *a setpoint.* Then the control system will communicate with the *relay* system to execute on-off to the pump, the entire system of control is *supplied* by a 12 volt adapter.

3.3 Installation of Automatic Control System on Irrigation Pump

3.3.1 Sensor Calibration

Sensor calibration is performed by conducting laboratory tests to look for correlations of ADC value on water content and pF. From the results of laboratory testing and calibration of sensors, value as listed in Table 2 was obtained. From the results of correlation, a linear equation to justify the value of the other ADC will be found. Correlation between ADC and pF is presented in Figure 4 and correlation of ADC and the water content is presented in Figure 5.

Table 2: Correlation between ADC value to pF and water content

Digital	pF	KA (m^3 / m^3)
845.96	0.00	64.23
837.24	2.01	43.03
834.94	2,54	37.44
827.73	4.20	19.92
824.26	5.00	11.48

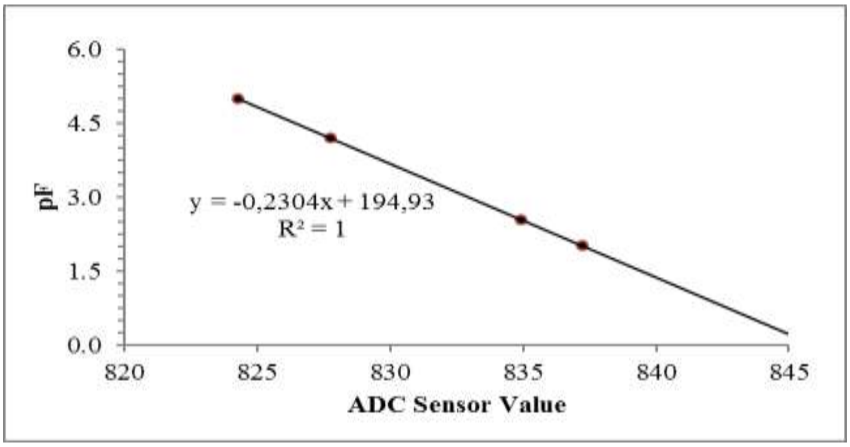

Figure 4: Correlation ween ADC and pF

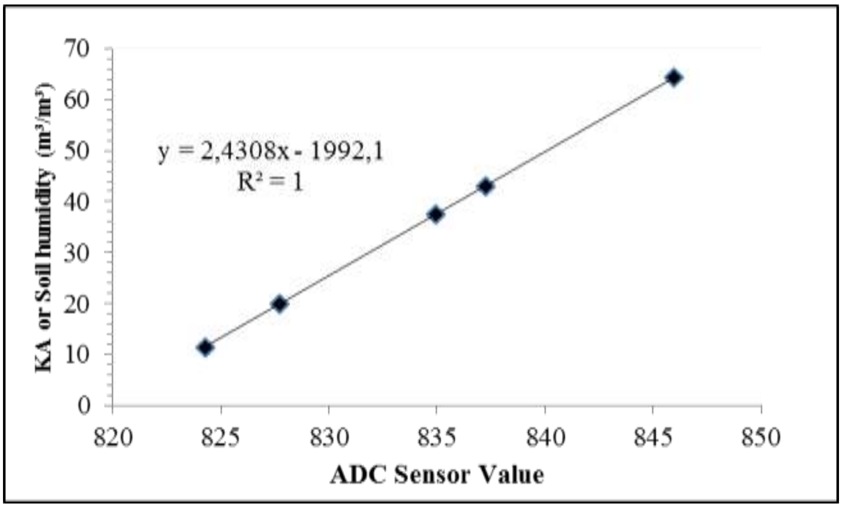

Figure 5: Correlation between ADC and KA

Calibration results showed a very linear relationship between the value of the voltage (volts) of the sensor output with pF and water content, which can be seen from the coefficient of determination sensor, which is 1. The correlation equation between ADC against pF value and moisture content, it will become the reference in making on-off control system of irrigation pumps with solar power. Nevertheless, the quantification of the value is the value of a model that only applies to the study site with a very common limiting factor.

3.3.2 Testing and Performance of Automated Pump Irrigation System

Provision of irrigation water (pump *on)* was designed when the sensor value reaches 4.1 (pF <4.2) and the discharge of irrigation water (pump *off)* when the sensor reaches 2.1. This is done because the ground water that is between field capacity and permanent wilting point is the water that can be used by the plant, which is called the available water (Islami and Utomo, 1995). *The set point* value for the pump cannot be used *on* 4.2 for this condition is a condition in which the plant cannot take the water contained in the soil or crop conditions have withered.

In this study the values of laboratory test results were emphasized and became a barrier to *set poit* program only. So if it was associated with the condition of the existing plant in the location study that value is not the pF field conditions value but a pF value control limitation system. The results of testing the control system is presented in Figure 6.

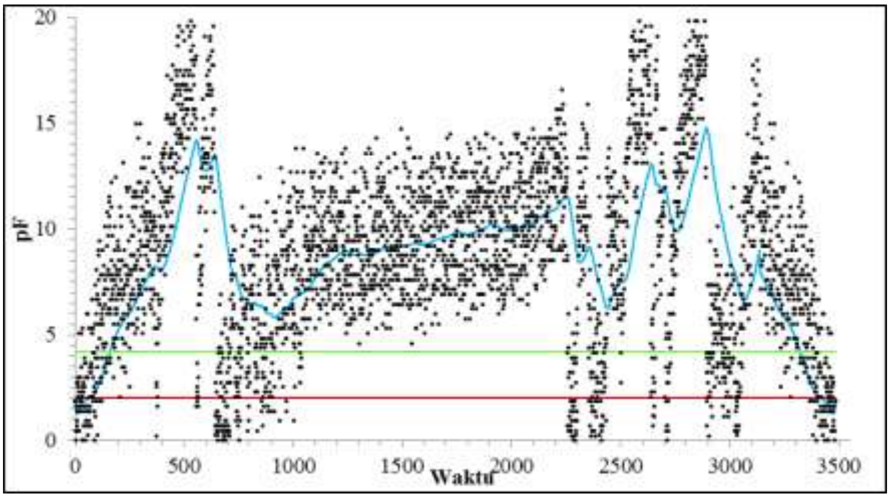

Figure 6: Results of testing control system

From Figure 6 there is a pF value that exceeds the value of 4.2. This condition is a bias of linear equations that are incorporated into the control system that are not given a limiting factor. If the control system a restriction value is given, the value above 4.2 will be read 4.2 automatically. This is not done to look the condition of sensor accuracy further and thus helps in the validation process.

The pumps that are used to test teksis irrigation system with solar power in the rainfed have a load of 125 watts, while the energy source *(battery)* used were12 volts and 100 Ah. After testing, the average debit pumps obtained was able to produce 17.45 liters / min or 0.29 liters / sec. A constant conversion water requirements for continuous discharge in an area is 1 l / s / ha [4]. This means that the resulting debit pump is able to meet the water needs for 1970 m^2 area, which is 0,197 liters / second. The technical test data of control sensor work (on-off pump) for 1970 m^2 land area, are presented in Table 3.

Table 3: Technical test data working sensor control (on-off pump)

repeat	Pump working long hours (minutes)	Volume (liters)	Water height (cm)
1	60.22	1050.84	0.05
2	71.05	1239.82	0.06
3	74.71	1303.69	0.07
4	74.85	1306.13	0.07
5	70,63	1232.49	0.06
Average	70.29		
S	5.97		
KV	8,49		

From Table 3, it can be seen that the coefficient of variation (CV) for a technical test pump working hours by 8, 49%, meaning that the level of uniformity data can be said to be uniform for <15%. This is according to [5], the smaller the coefficient of variation, the more uniform the data, and vice versa, the greater the value of the coefficient of variation, the more non-uniform the data.

The water level average that can be achieved for the average working hours of pumps for 70.29 minutes was 0.06 cm with a land area of 1970 $m^{2.}$. The water level achieved in this study are already on the adjustment range *of water level* that has been done by [6], the setting up *of water level* between 0 cm to 5 cm in automatic irrigation pipe in paddy fields can maintain soil moisture in pF under 2, which means the land is at saturated condition.

IV. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusion

The experimental results indicated that the automatic control system using a microcontroller can function properly in controlling the pump, with pF reference in the land as specified *setpoint* value is 4.1 pF on *on* pump and 2.1 on *off* pump. The average working time of pump (on-off) for 1970 m^2 area is 60-75 minutes to average debit of 17.45 m^3 / min.

4.2 Suggestion

In determining the *setpoint* value for on-off control of the pump, the monitoring data in long span of time is needed, so that the value obtained could represent the actual field conditions and bias for linear equations to be incorporated into the control system can be minimized.

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