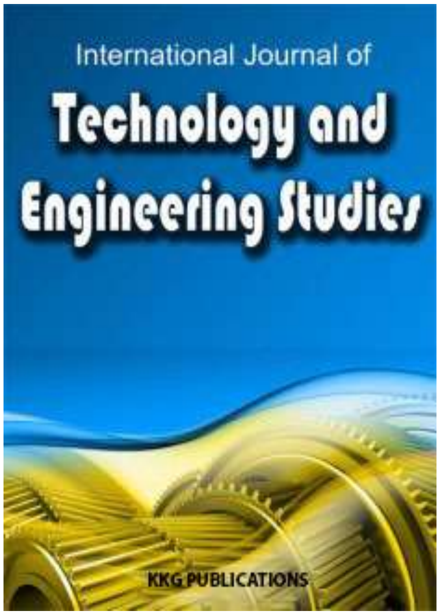

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HILMAN SYAEFUL ALAM [1], TRIYA HAIYUNNISA [2], BAHRUDIN [3]

[1, 2, 3] Technical Implementation Unit for Instrumentation Development, Indonesian Institute of Sciences, Jl. Sangkuriang Komplek LIPI Gedung 30 Bandung, Indonesia

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COMPARATIVE ANALYSIS OF P, PI, AND PID CONTROLLERS OPTIMIZED BY GENETIC ALGORITHM ON CONTROLLING DRIP IRRIGATION SYSTEM

HILMAN SYAEFUL ALAM [1*], TRIYA HAIYUNNISA [2], BAHRUDIN [3]

[1, 2, 3] Technical Implementation Unit for Instrumentation Development, Indonesian Institute of Sciences, Jl. Sangkuriang Komplek LIPI Gedung 30 Bandung, Indonesia

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Set Point
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Abstract. This study calculated the desired actuator of the control valve that aimed to control the water flow to the field. In this paper, P, PI, and PID controllers are optimized by the Genetic Algorithm (GA) optimization technique copied from the process of biological evolution. Drip irrigation is a method of watering plants with a volume of water approaching the consumptive use (CU) of the plants. In this drip irrigation system, controlled items are humidity and pressure sensors obtained from the readings of those sensors. By determining the setpoint and using P, PI, or PID controller applied, the control system's performance could be defined. The output response of the control system of Drip Irrigation is good; only the value of the setpoint has not been reached. Therefore proportional controller (Kp) is needed as the gain of the system. The best value of the P controller (Kp) for the drip irrigation system is 74.95, where the max overshoot is only 0.0231 bar or 1.92%, and the steady-state condition has been reached at 24.95 seconds with no error steady state.

INTRODUCTION

Agriculture is the largest consumer of global freshwater, accounting for around 70% of withdrawals as irrigation [1], [2]. Increasing water use efficiency by using improved irrigation techniques is a priority for the agricultural sector [3]. The consumption of water in plant is, in practice, mostly determined by the energy available and/or by the vapor pressure deficit of the air present [4]. Improved irrigation techniques have been used to conserve water in the past [3]. According to A.M Michael, 1991, drip irrigation is a method of watering plants with a volume of water approaching the consumptive use (CU) of the plants [5] [6]. This method distributes water directly to the parts of a plant where it is needed the most.

In drip irrigation system, controlled items are humidity and pressure sensors, which are obtained from the readings of those sensors, we compute the desired actuator of control valve that aimed to control the water flow to the field. By determining the set point, and using P, PI, or PID controller applied, the performance of the control system could be defined. An ideal control system has fast response (short rise time), quick to reach steady state condition with no error, no oscillations and higher stability.

A conventional PID controller consists of three components: The proportional term produces an output value that is proportional to the current error value. The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. Derivative control is used to reduce the magnitude of the overshoot produced by the integral component and improve the combined controller process stability [7].

In this paper, P, PI, and PID controllers are optimized by Genetic Algorithm. Genetic Algorithm (GA) is optimization technique copied from the process of biological evolution [8]. The main advantage of the GA formulation is that fairly accurate results may be obtained using a very simple algorithm. The GA is basically based on an iterative process of selection, recombination, mutation and evaluation. GA has parallel search techniques, which emulate natural genetic operations. Due to its high potential for optimization, GA has received great attention in control systems such as the search of optimal controller parameter [5]. The control system includes controller that has been determined by GA and simulated to see the performance, and being compared for every response of the controller applied.

DRIP IRRIGATION CONTROL SYSTEM

In this paper, the pressure in the pressure tank is maintained in 1.2 bars, so the control valve must be opened to decrease the pressure in tank. The humidity sensor reading aimed to make sure when the field needs to be watered. The humidity sensor will turn off the water pump to water the plant, with the opening of control valve that is controlled by pressure sensor reading.

In drip irrigation system, the irrigation starts when the humidity sensor's reading shows that the strawberry field needs to be watered. The watering process is carried out by control

*Corresponding author: Hilman Syaeful Alam
E-mail: hilm003@lipi.go.id

valve where the source of water is from pressure tank. In pressure tank, the pressure is controlled by pressure sensor where the pressure is maintained in pressure 1.2 bars. Here is the scheme of drip irrigation system.

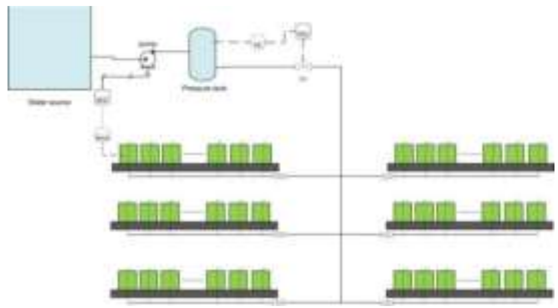

Fig. 1. The process of drip irrigation system

In this drip irrigation system, the process variable is control valve. Pressure sensor is used to measure the process variable and provide feedback to the control system. The set point is the desired value for the process variable. The difference between the process variable and the set point is used by the control system algorithm (compensator) to determine the desired actuator output to drive the system (plant). Here are the steps of changing to the set point shown in fig 1.

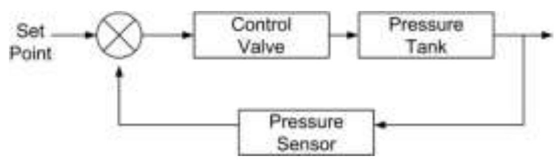

Fig. 2. Block diagram of drip irrigation control system

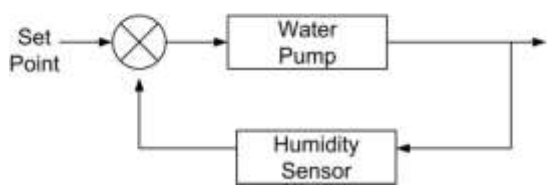

Fig. 3. Block diagram of pressure tank

The block diagram of pressure tank is affected by the water pump. The pump will be turned off if the humidity sensor reads that the soil is needed to be watered.

MATHEMATICAL MODELLING

Before looking for what controller would be applied, first the transfer function of each component is determined in block diagram.

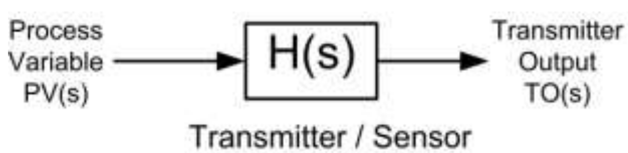

Fig. 4. Block diagram of sensor/transmitter

The transfer function of the sensor/transmitter combination relates its output signal to its input, which is the process variable; this is shown in Fig 4 [8]. The simplest form of the transfer function is a first-order lag:

$$H(s) = \frac{TO(s)}{PV(s)} = \frac{K_T}{\tau_T s+1} \qquad (1)$$

Where

K_T = transmitter / sensor gain = $\frac{span\ output\ signal}{span\ measured\ variable}$

τ_T = transmitter / sensor time constant

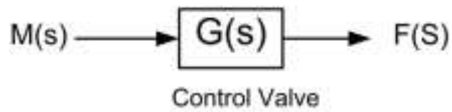

Fig. 5. Block diagram of control valve

The block diagram of Fig 3 assumes that the pressure drop across the valve either is constant or is a function of flow only. The transfer function of control valve could be defined as [8]

$$G(s) = \frac{K_v}{\tau_v s+1} \qquad (2)$$

where

K_v = control valve gain = $\frac{span\ output}{span\ input}$

τ_v = control valve time constant

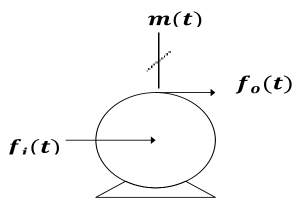

Fig. 6. Block diagram of water pump

Transfer function of water pump could be defined as [9]:

$$F_o(s) = \frac{K_p}{\tau_p s+1}\ \mathrm{M(s)} \qquad (3)$$

Where

$$M(s) = -\frac{B}{s}$$

B = signal change when pump is running

K_p= pump gain = $\frac{span\ output}{span\ input}$

τ_p= pump time constant

From the equations of the transfer function of each component in plant, we could be looking for the transfer function of the plant and simulate the plant system. The transfer function of plant is:

$$\frac{44.096s^3+11.9059s^2+0.90948s+0.01378}{96s^5+1305.92s^4+3551.5232s^3+904.1458s^2+68.3157s+1.0329} \qquad (4)$$

The response of the plant is shown in fig below:

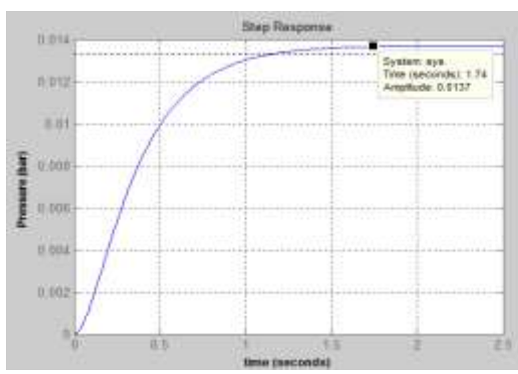

Fig. 7. Step response of Drip Irrigation System

Designing of P, PI, PID Controller Using Genetic Algorithm

The PID controller has 3 terms. The proportional term P corresponds to proportional control. The integral time I gives a control action that is proportional to the time integral of the error. This ensures that the steady state error becomes zero. The derivative term D is proportional to the time derivative of the control error. This term allows prediction of the future error [10].

Determining the appropriate combination value of controller applied is difficult. Random search in this paper is using Genetic Algorithm process.

Before applying the controller in drip irrigation system, first determine initial GA parameter and fitness function. GA works on an iterative process of selection, recombination, mutation and evaluation. Before iteration process begins, first determine initial population randomly with double vector type. It helps to find the P, PI, or PID controllers in a real number where each individual represented the controller itself.

Deciding of population size is an important issue while applying genetic algorithms (GAs). It is recommended by the researchers, that the population size should be of about 20 to 30 chromosomes. A very big population size consumes more time for finding optimum solution, which may deteriorate the performance of genetic algorithms (GAs) [11]. This population size is determined randomly. In this paper, the population size is 20.

In Genetic Algorithm process, generation is represented as sum of iteration of the process. The process would stop when the process has already found the best value of fitness function and already reached the maximum generation. In this paper, the generation is 100.

Fitness function is used to look for the appropriate controller to decrease overshoot, accelerate rise time, eliminate error steady state, and be quick to reach steady state condition. Thus, the fitness function is using Mean Square Error (MSE) criteria of the controlled process.

$$MSE = \frac{(x_1 - x_{11})^2 + (x_2 - x_{22})^2 + \cdots + (x_n - x_{nn})^2}{n} \quad (5)$$

During evolution process, Genetic Algorithm is looking for appropriate value of controllers to minimize the fitness function F(x). MSE equation above is of individual quality. The x represents the reference system value and output of the system.

$$F(x) = \min(MSE) \quad (6)$$

In evolution process, Selection is basically the process of choosing two parents from the population for crossing [12] [13]. Selection process produces the next generation. In this paper, kind of selection chosen is uniform selection.

Crossover in every population can be calculated by the formula $P_c * pop\_size$, where P_c is probability of crossover. The higher P_c applied, the faster new structure introduced. P_c is 0.628 [13][14].

Mutation is used to increase population variations, which operated randomly where every basic unit in structure has probability interchanged. Mutation in every generation can be calculated by the formula $P_m * pop_{size} * L$, where $P_m$probability of mutation used is 0.01, and L is structure length in every individual [13] [14]. The process of choosing the best controller to be applied on Drip Irrigation Using GA could be described by flowchart below.

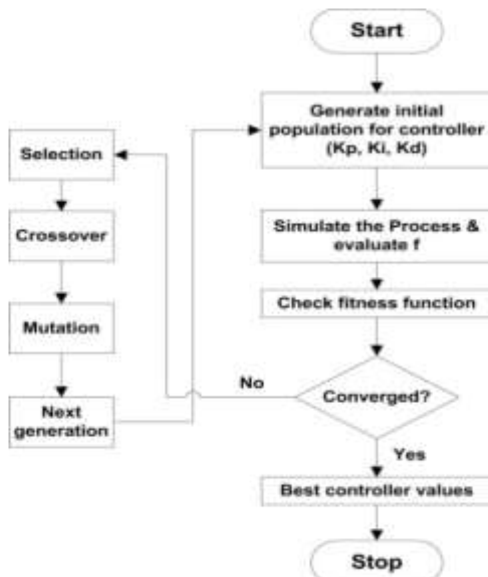

Fig. 8. Flowchart of GA on choosing the best controller of drip irrigation system [15]

RESULTS AND DISCUSSION

By applying P, PI, or PID controller of drip irrigation system, the controller would simulate to know which controller is the best to be applied on. The traditional way to control a process is to measure the variable that is to be controlled, compare its value with the desired value (the set point to the controller) and feed the difference (the error) into a feedback controller that will change a manipulated variable to drive the controlled variable back to the desired value. Information is thus "feedback" from the controlled variable to a manipulated variable, as sketched in Fig. 5 [16].

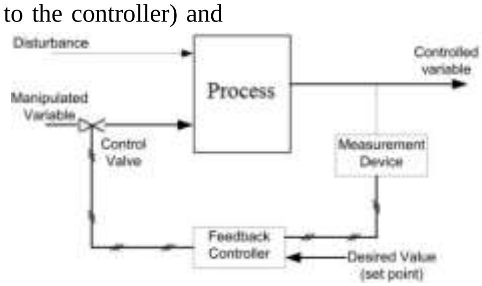

Fig. 9. Feedback control loop

From the Genetic Algorithm process, the simulations of 3 controllers applied are shown in figure 10. The best value of P controller (Kp) for drip irrigation system is 74.95, where the max overshoot is only 0.0231 bar or 1.92% and the steady state condition has been reached at 24.95 seconds with no steady state error.

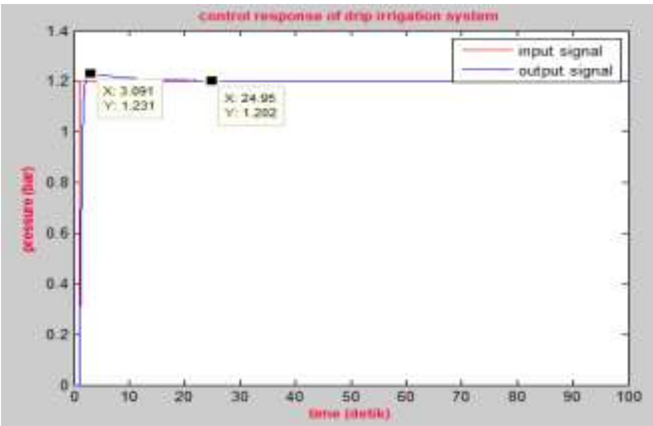

Fig. 10. Drip irrigation control system using P controller (Kp)

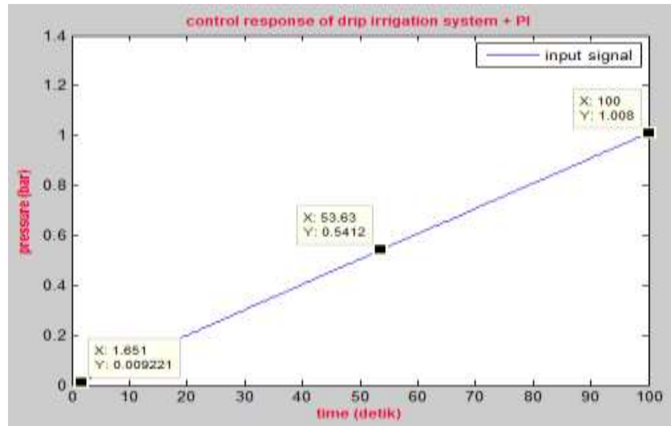

Fig. 11. Drip irrigation control system using PI Controller

From Genetic Algorithm process, the proportional and integral controllers are obtained Kp = 6.399 and Ki = 9.095. The output response of the PI controller is shown in fig 10. Based on the output response of PI controller above, the graphic is tended to be linear curve. It was caused by using I controller (Ki). The integral controller could be defined as:

$$K_i(t) = \frac{1}{T_i}\int e(t) \quad (7)$$

Where the laplace of Ki function is

$$K_i(s) = \frac{1}{T_i s}\, E(s) \quad (8)$$

The equation above is the cause of increasing the order of system, that will cause steady-state error appear all time, as shown in fig 7. As same as PI controller, in the using of PID controller, the output response also tends to be linear. It is because of the using of Integral controller (Ki), thus the graphic is like output response of PI controller where the value will always increase as the time increases. In the fig 8 below, Kp = 9.662, Ki = 9.6302, and Kd = 1.937.

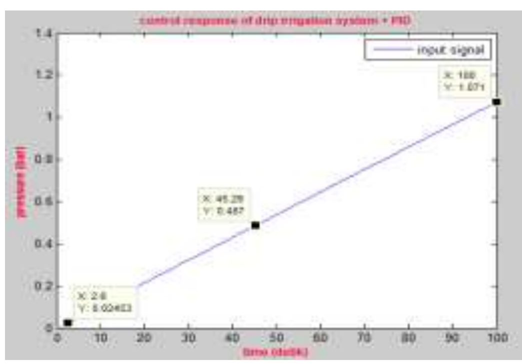

Fig. 12.

CONCLUSION AND RECOMMENDATIIONS

Basically, output response of the control system of Drip Irrigation is good, only the value of the set point has not been reached. Therefore proportional controller (Kp) is needed as the gain of the system, thus the set point could be reached. While by adding the integral controller (Ki), the output response becomes worse, due to the characteristic of integral controller itself that causes the increase in system order. Thus, the output response will have steady state error all time.

Declaration of Conflicting Interests

There are no conflicts involved in this work.

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