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Design of PID Controller for Irrigation system

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Abstract:

The main aim of the paper is to design the PID controller for irrigation system. The various factors such as temperature and humidity of agriculture environment is monitored. Monitoring temperature and humidity parameters are important for obtaining high quality environment. The feature of this paper includes the design of PID controller, mathematical models of inputs and dc motor, Zeigler- Nichol's tunning method for PID controller. The project is designed using PID controller, MATLAB and Simulink library tools. The temperature sensor and humidity sensor are used to detect the temperature and humidity parameters of soil. This paper also includes the design and analysis of DC Motor that can be controlled by PID controller. The development of PID controller with mathematical model of input parameters and dc motor is simulated using Zeigler-Nichol's method and automatic tuning method. The simulated results are described to demonstrate the effectiveness of control system's performance.

Keywords **—** PID Controller, Temperature & Humidity Sensors, Irrigation System, MATLAB/Simulink.

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I. INTRODUCTION

Agriculture is the backbone of our country and one of the leading factors which impact the economy of the country. The various advanced technologies are implemented in agriculture field to make the farming process quick and easier. One among the advanced technology is the automatic irrigation system. There are various techniques which has been implemented for automatic irrigation system. The various techniques used are PID & Fuzzy Logic based controller and Artificial Neural Network & ON/OFF based controller for irrigation system. Wireless Fuzzy Controller for Drip Irrigation: The fuzzy logic irrigation system based on AVR microcontroller is assigned and a low-cost feature based on embedded platform for agriculture system is developed [1]. Automation of Irrigation System using ANN based Controller: The Artificial Neural Network (ANN) based irrigation system includes the modelling of input parameters like temperature, soil moisture, humidity and radiation and also it uses the appropriate method, evapotranspiration and type of crops, ecological conditions, amount of water needed for irrigation is estimated [2]. Intelligent

Control Based Fuzzy Logic for Automation of Greenhouse Irrigation System and Evaluation in relation to conventional Systems: The solution for an irrigation system based on fuzzy logic methodology describes the general problem and physical control modes of irrigation and developing Fuzzy Logic Controller (FLC) prototype based on Mamdani Controller and also provides an example that shows the simplicity in designing and constructing a system [3]. Application of Fuzzy Logic in Water Irrigation System: The paper includes a fuzzy controller design and the controller is simulated using MATLAB software for water irrigation issue [4]. Simulation and Analysis of Irrigation Controller Based on Fuzzy Logic: Automation irrigation control system is designed and simulated using MATLAB simulation tools. Electric motor with hybrid setup and tube well are considered as inputs and water level, time, area is considered as outputs to calculate the efficiency of controller [5].

II. IRRIGATION SYSTEM

Irrigation is the application of delivering water for agriculture fields. The process of irrigation involves the pumping of water using motor from water resources to the crops according to their need. There are various techniques of irrigation such as Fuzzy Controller, ANN Controller, ON/OFF Controller based irrigation system. In this paper, irrigation with sensors and controller is used. There are two types of controllers which are used to control the irrigation system. Open Loop control System and Closed Loop Control System. Open Loop Control System works on pre-set action like using timer. Closed Loop Control System works on feedback response where it receives feedback from sensors, make decisions and apply the output of the decisions to the irrigation system.

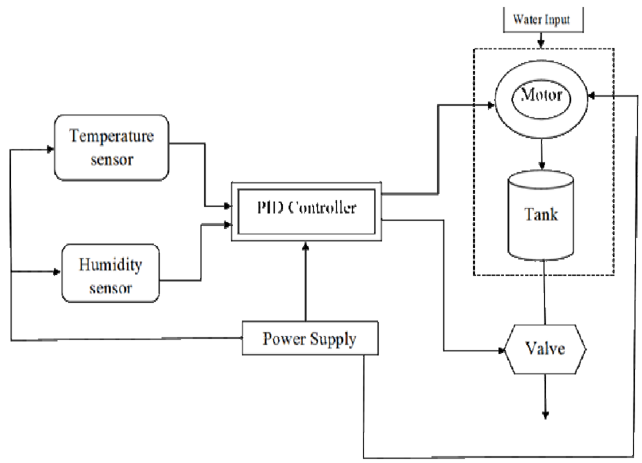

FIG.1 BLOCK DIAGRAM OF IRRIGATION CONTROL SYSTEM

The block diagram of Irrigation Control System is shown in fig.1. Block diagram consist of PID controller for controlling the valves, motor, water tank, temperature and humidity sensors which are used to measures the temperature and humidity of soil in agriculture field. The PID controller will control the flow of water based on the received feedback from the sensors and also PID controls the speed of motor by considering the armature voltage as input and speed as output. The control system is developed using temperature and humidity sensors that can be placed on root zone of crops for measuring the temperature and humidity of soil, by using the feedback control mechanism with a controller which regulates the flow of water in to the agriculture field in real time based on the instant temperature and humidity values. The proposed PID controller-based irrigation system is simulated using MATLAB and the Simulink model of Irrigation System is shown in fig.2. PID controller is simulated by MATLAB as in figure 2. Input signals are taken as sinewave and step connected to feedback signal with summing point. Transfer functions are modelled by considering the temperature and humidity transfer functions.

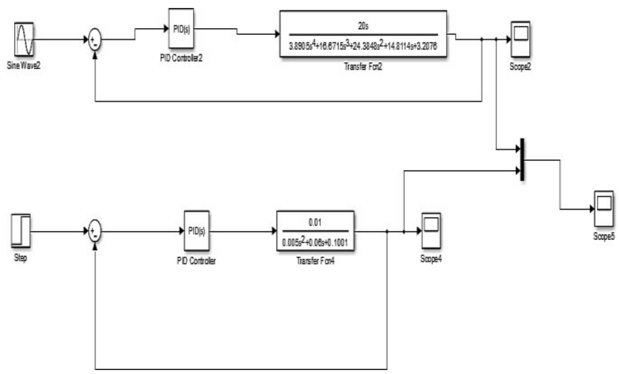

FIG.2. SIMULINK MODEL OF IRRIGATION SYSTEM

III. MATHEMATICAL MODELING OF INPUT SIGNALS

Consider the temperature (1) and humidity (2) parameters of soil transfer functions.

For temperature: $\frac{20}{s+1}$ ⟶ (1)

For humidity: $\frac{1}{s+1}$ ⟶ (2)

cascading the two input signals (1) & (2), we get,

$$\left(\frac{20}{s+1}\right) * \left(\frac{20}{s+2}\right) = \frac{20}{(s+1)(s+2)}$$

On simplification we get, $\frac{20}{s^2+3s+2}$ ⟶ (3)

IV. DESIGN OF PID CONTROLLER

To design the PID controller, consider the standard equation and transfer function of PID controller. The standard equation of PID controller is:

$$u(t) = k_p e(t) + k_i \int_0^t e(\tau)d\tau + k_d \frac{d}{dt} e(t) \longrightarrow (4)$$

Where, u(t) is output response, e(t) is error, t is instantaneous time, □ is integration variable varies from 0 to t, □□ is proportional gain, □□ is integral gain, □□ is derivative gain.

The transfer function of PID controller is:

$$G(s) = k_p\left(1 + \left(\frac{1}{sT_i}\right) + sT_d\right) \longrightarrow (5)$$

Where, □□ is integral time and □□ is derivative time.

V. MATHEMATICAL MODELING OF DC MOTOR

Design Requirements of Motor:

Consider that, the motor runs at 0.1 rad/sec in steady state for an input voltage of 1 volt. The motor should rotate at the desired speed, that the steady state error of motor should be less than 1%. The motor must accelerate to its steady state speed as soon as it turns ON. Since motor speeds faster than reference may damage the equipment, the settling time should be less than 2 sec and overshoot should be less than 5%.

Consider the physical set up of DC Motor show in fig.3.

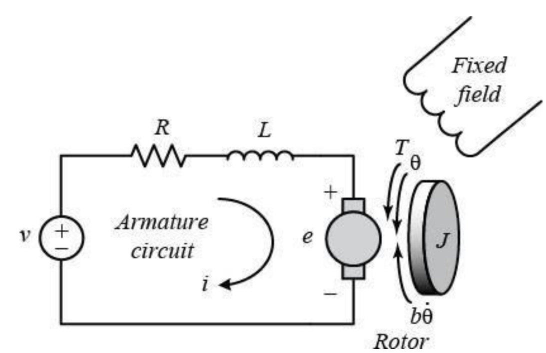

FIG 3. PHYSICAL SET UP OF DC MOTOR

From figure, Voltage V is input applied to motors armature. Rotational speed of shaft $\frac{d\theta}{dt}$ is output.

Torque T generated by motor is proportional to the armature current and the strength of magnetic field. Assume that the magnetic field is constant. Such that the motor torque is proportional to only armature current I by a constant factor of k_t as shown in equation 6 which is referred as armature-controlled motor.

$$T = k_t i \longrightarrow \quad (6)$$

The back emf e is proportional to angular velocity θ of shaft by a constant factor k_e.

$$e = k_e \theta \longrightarrow \quad (7)$$

As per standard unit, torque and back emf constants are equal that is $k_t = k_e$. Therefore, for representing both the constants, we use K.

$$K = k_t = k_e \longrightarrow \quad (8)$$

From fig 3, deriving a governing equation base on Newton's 2nd law and Kirchhoff's voltage law.

$$J\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} = k_i \longrightarrow \quad (9)$$

$$L\frac{di}{dt} + R.i = V - K\frac{d\theta}{dt} \longrightarrow \quad (10)$$

Where, J is moment of inertia of the rotor, B is motor viscous friction constant, k_i is constant factor, L is electrical inductance, R is electrical resistance, V is voltage source.

Applying Laplace transform to 9 and 10 equations, we get Laplace variable equation as,

$$Js^2\theta(s) + b\,s\,\theta(s) = K.I(s) \longrightarrow \quad (11)$$

□□□(□)+□□(□)=□(□)−□□□(□) ⟶ (12)

On simplification we get,

$$\frac{\theta(s)}{V(s)} = \frac{k}{s[(Js+b)(Ls+R)+K^2]} \longrightarrow \quad (13)$$

□(□) / □(□) = □ / [(□□+□)(□□+□)+□²] = □(□) ⟶ (14)

Assuming the physical parameters for DC motor and applying into 14th equation, we get a closed loop system.

$J = 0.01\ kg.m^2$, $B = 0.1\ N.m.s$, $k_e = 0.01\ V$/rad/sec, $k_t = 0.01\ Nm$/Amp, R=1 Ω, L=0.5H.

$$p(s) = \frac{0.01}{0.005s^2 + 0.06s + 0.1001} \longrightarrow \quad (15)$$

V. ZIEGLER – NICHOLS TUNNING METHOD

Z-N tunning method is used to determine the gain parameters of PID controller. Gain parameters are k_p, k_i and k_d. There are two methods of Z-N tunning technique. Process reaction curve method and Ultimate gain (Ku) & Ultimate period method (Pu). Here, ultimate period and ultimate gain method is used to tune the PID controller and also automatic tuning is used.

The rules to tune the PID using Ku and Pu method are:

1. Determine the value of proportional gain K keeping integral time (T_i) to 999 or ∞ and derivative time (T_d) to 0.
2. Adjust the value of K, until the oscillations have constant amplitude. Whenever set point varies, it creates a small disturbance in the feedback loop.
3. Note down the ultimate gain value Ku and ultimate period of oscillation Pu.
4. Using the values of Ku and Pu in closed loop equations of Z-N for required setting of controller.

Closed loop equations are:

$$\mathrm{Kp} = \frac{ku}{1.7} \quad Ti = \frac{Pu}{2} \quad Td = \frac{Pu}{8}$$

$$Ki = \frac{Kp}{ti} \quad Kd = kpTd$$

Solving equation 3 & 5, we get,

$$\frac{20s}{(s^4Kd+s^3(Kd+KP)+s^2(2Kd+3Kp+Ki)+s(2Kp+3Ki)+2Ki}$$

Following the Z-N rules, the gain parameters are obtained as:

$$\mathrm{Kp} = 5, \; Ki = 1.6038, \; Kd = 3.890$$

Substituting the above values in above equation, we get the Ziegler-Nichols equation for irrigation system.

$$\frac{20s}{8905s^4+16.6715s^3+24.3848s^2+14.8114s+3.2076}$$

VI. SIMULATION RESULT

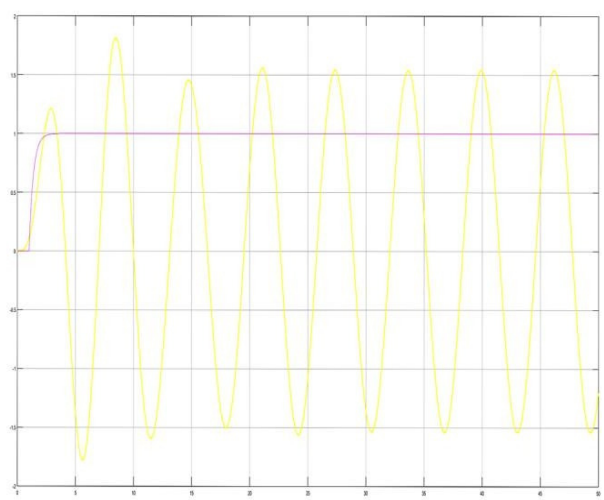

FIG 4. SIMULATION OUTPUT OF IRRIGATION SYSTEM

Figure 4 shows the output of Simulink model of irrigation system. The pink graph represents the stable operation of motor at unity. The overshoot and settling time are under 5% and 2 seconds. The yellow graph represents the sustained operation of sensing system where water flows out of to the crops field without any interruption. Thus, the irrigation control system gives stable and sustained operation.

VII. CONCLUSION

The paper presents the Design of PID Controller for Irrigation system and also it includes the design of DC motor used in irrigation control system. The simulation result shows that the irrigation system is stable, achieving a sustained operation and design of reliable irrigation controller using PID controller is achieved. The proposed system favours in utilizing a water in sensible manner and very useful in water limited geographically isolated area.

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