ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

Hierarchical PI Control of an Irrigation Canal

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ABSTRACT: In this paper, it presents the concept of hierarchical PI control of an irrigation canal. Water losses in the irrigation canals are reduced by improving the control system. The water level and inflow to the canal are controlled using gates located along the canals. In this paper we consider the PI controller to control the water level and inflow to the canal. The approach is event driven. The system comprises of water level sensors are placed in an irrigation canals and each sensor data is collected by PI controller, depending upon the data event the motor switching action is controlled to maintain the desired water level of the canal. Zigbee module connected to the controller collects the water level and inflow status of the canal and sends it to the control room for further analysis. Simulation-based case study by using a numerical model of a real canal is presented.

KEYWORDS: PI control, Irrigation canals, event driven control, Zigbee, MATLAB and Simulink.

I.INTRODUCTION

IRRIGATION is the artificial application of water for the purpose of supplying moisture essential for the plant growth. It plays important role in increasing the food production, prolong the effective growing periods in areas with dry seasons, and to ensure a stable production in traditional dry land farming systems, subjected to vagaries of rainfall. The purpose of irrigation scheduling is to maximize the exact amount of water needed to replenish the soil moisture to the desired level; the scheduling is based on – 1. When to irrigate 2. How much to irrigate. With that in mind, irrigation canals are often used to deliver water to farmers from a source like a river, a lake, or a dam. In fact, irrigation systems originated as early as 6000 BC in ancient Egypt and Mesopotamia. Nowadays, more than 90% of the total consumptive water use is generated by irrigation. Therefore, it is of the highest importance to be able to operate the irrigation canals efficiently and dependably.

Efficient water management plays an important role in the irrigated agricultural cropping systems. In order to produce ―more crop per drop, growers in (semi) arid regions are currently exploring irrigation techniques in the range from using less fresh water. One of them is making agriculture in a manner of sense, which uses a different type of sensors. A site-specific sensor-based irrigation control system is a potential solution to optimize yields and maximize water use efficiency for fields with variation in water availability due to different soil characteristics or crop water needs and site-specific controlling irrigation valves. Decision making process with the controls is a viable option for determining when and where to irrigate, and how much water to use. Temporal monitoring of soil moisture at different growth stages of the crop could prevent water stress and improve the crop yield.

In this paper, it proposes the hierarchical control of an irrigation canal using PI controller. The hierarchical controller controls the irrigation canal. The controller consists of two control layers. The lower layers (canals) are based on the equipment present in the field, moisture sensors, used for upstream control. The higher layer—the Coordinator—is a Proportional Integral (PI) Controller, the purpose of which is to control the inflow to the canal.

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The rest of the paper organized as follows: Section II gives system model. Section III gives brief description of the proposed system. Section IV discusses about the working of various blocks of the proposed system. Section V gives the simulation model of the proposed system. Section VI discusses the results and discussion and section VII concludes the paper.

II.SYSTEM MODEL

Fig.1 System Model

System model mainly consists of controller, canals, water tank, motors, moisture sensors, display unit and ZigBee module. The moisture sensors are placed in canals to measure the water content in the soil of the particular canal. The measured value is given to the controller, depends upon the measured value the controller will take the necessary actions to turn ON/OFF the motor to control the inflow to the respective canal. The moisture level and the status of the motor (ON/OFF) are displayed and linked radio transceivers that allowed the transfer of soil moisture level and motor status to control room that uses ZigBee technology.

III.SYSTEM MODEL HARDWARE DESCRIPTION

This section describes the hardware components and their functions in the proposed system.

A. PIC16F877A Microcontroller

The main part of the project is the PIC microcontroller, which offers high performance and very low power consumption. It is based on Reduced Instruction Set Computer (RISC) principles, and the instruction set and related decode mechanism are much simpler than those of micro programmed Complex Instruction Set Computers (CISC). The microcontroller monitors the moisture level through the port pins and controls the motor switching action.

B. Soil Moisture Sensor

The Soil Moisture Sensor is used to measure the volumetric water content of the soil. It converts the relative humidity into output voltage. The sensed data are sent to the ports of the microcontroller.

A. ZigBee

Zigbee technology is based on short range WSN and it was selected for this battery operated sensor network because of its low cost, low power consumption and greater useful range in comparison with other wireless technologies. The zigbee devices operate in industrial, scientific and medical fields. The zigbee device transmits the data from the controller to the control room.

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IV.METHODOLOGY OF WORKING

The switching action is achieved using relays. The relay is driven by the L293D driver, which in fact is activated by the output pin of the microcontroller after being processed by a feedback from the soil moisture sensor which is placed in a dry soil. Once the L293D is activated it drives the corresponding relay to which it is connected to.

At the beginning of the hardware setup, the soil moisture sensor is placed in a dry soil, which contains 0% volumetric water content, therefore the sensor output is LOW, which is given to the microcontroller as a feedback signal. As the microcontroller receives the signal as LOW, it activates the L293D, it drives the corresponding relay, which in turn turns the corresponding motor ON. Water flows through the canal to the pool.

Once the volumetric water content in soil is 45%, the sensor sends the HIGH signal to the microcontroller as a feedback signal. As the microcontroller receives the signal as HIGH, it deactivates the L293D, it drives the corresponding relay, which in turn turns the corresponding motor OFF. This process continues till the power to the hardware setup is switched off.

V.SIMULINK MODEL

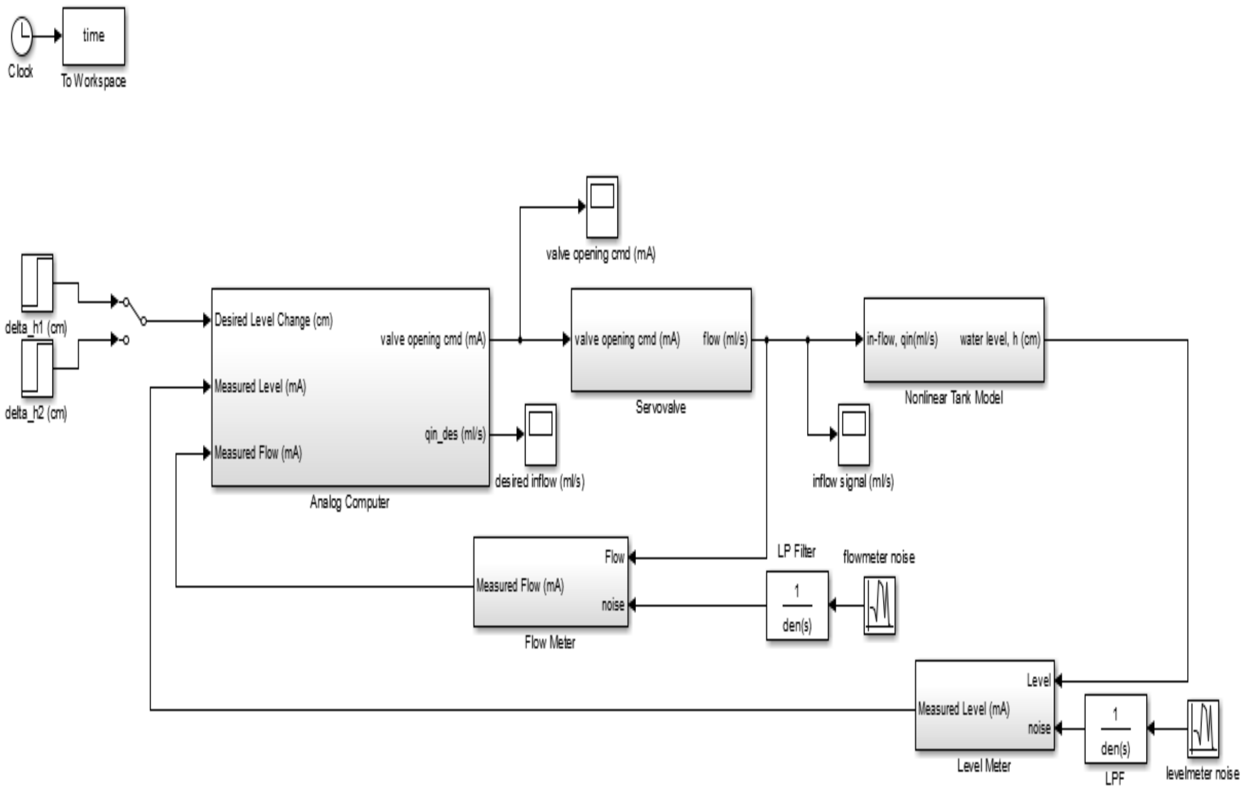

Fig. 2 Simulink Model

Fig. 2 describes the Simulink model of the proposed system.

The Simulink model consists of following subsystems:

A. Analog Computer

The analog computer subsystem is the heart of the water tank model. It consists of feedforward controller, used to reduce the effect of the measured disturbance on the output. Mu synthesis robust control method is used for the better performance of the system. The desired flow is calculated within this subsystem, and then the difference between the desired flow and the measured flow (one of the input of analog computer subsystem), the error signal is given to the valve controller (which is the subsystem of analog computer subsystem). The valve controller is the PI controller, which calculates the valve opening command output (which is one of the output of analog computer subsystem). The valve opening command output is given as an input to the servovalve subsystem.

B. Servovalve

The servovalve subsystem is used to calculate the measured inflow (in millilitre per second) to the canal. It consists of interpreted MATLAB function, rate limiter and a saturation block. Rate limiter controls the rate of change of variable and is used to avoid abrupt change of values that causes transient and jerky operation. It is used to generate a smooth profile waveform while changing from one speed range to another speed range. Saturation is used to limit the waveform range between upper and lower limits. The valve opening command (mA) input is given to the interpreted MATLAB function, which converts the command into flow (mililitre/second). The signal out from MATLAB function is passed through the rate limiter, which generates smooth profile waveform, and then the signal is passed through a saturation block with a gain of 62.1 with the range from 0 to 69.

A. Flow Meter

It converts the canal inflow in millilitre per second into the measured inflow in milli Ampere.

B. Nonlinear Tank Model

It converts the canal inflow (q_{in} in millilitre per second) into water level (h, in centimeter).

C. Level Meter

It converts the water level of the canal, h in centimeter into measured level of the canal in milli Ampere.

VI.RESULTS AND ANALYSIS

In the fig. 3, it shows the closed loop non linear response of the canal system.

Step response characteristics of the fig.3 are:

Rise Time: 23.7662 seconds

Settling Time: 125 seconds

Overshoot: 2.0651%

Peak: 68.8940 mm

Peak Time: 54.8000 seconds

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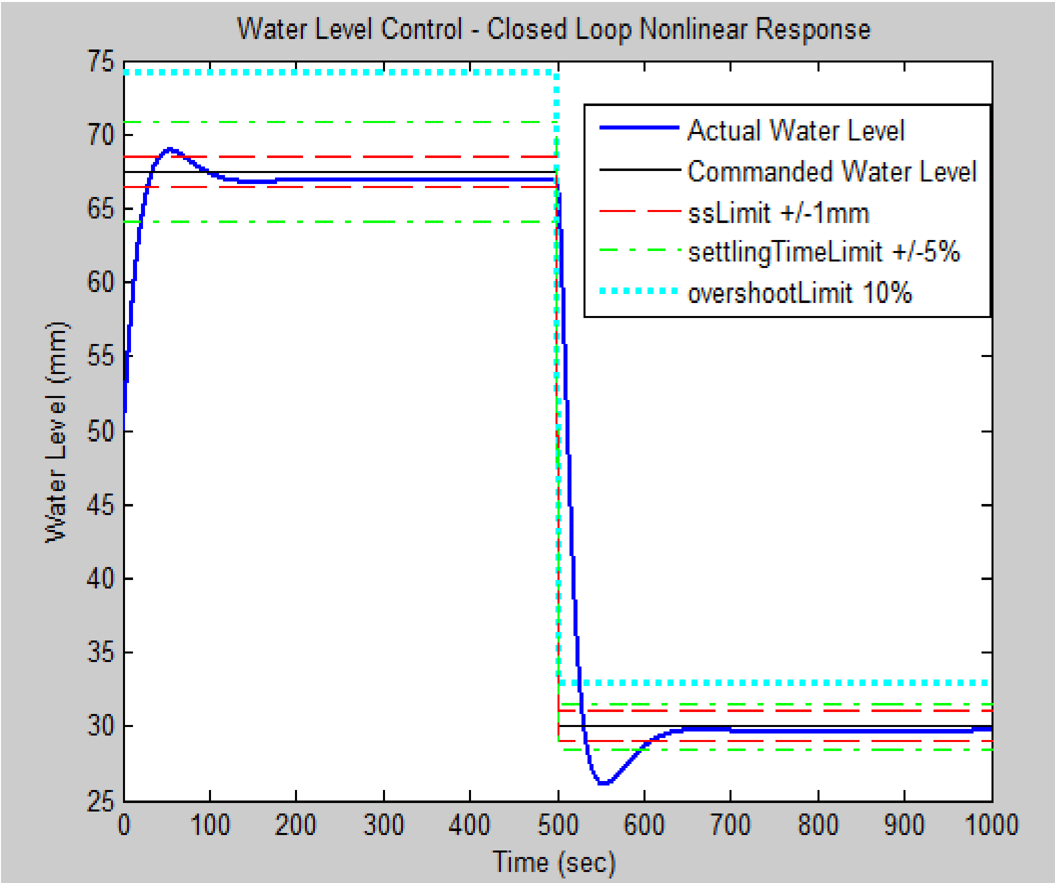

Fig. 3 Closed loop non linear response of the canal system

Fig. 4 shows two subplots, subplot 1 shows the graph of valve opening current command (mA) Vs time (sec) and subplot 2 shows the actual valve opening simulated signal (ml/sec) Vs time (sec).

Valve opening current command is the output of the analog computer subsystem it is in terms of milli ampere. Depends up on the water level of the canal, which is the difference between the desired level and the measured level, the valve opening current command varies.

The actual valve opening simulated signal is generated within the servovalve subsystem. The current command is converted into signal it is in millilitre per second.

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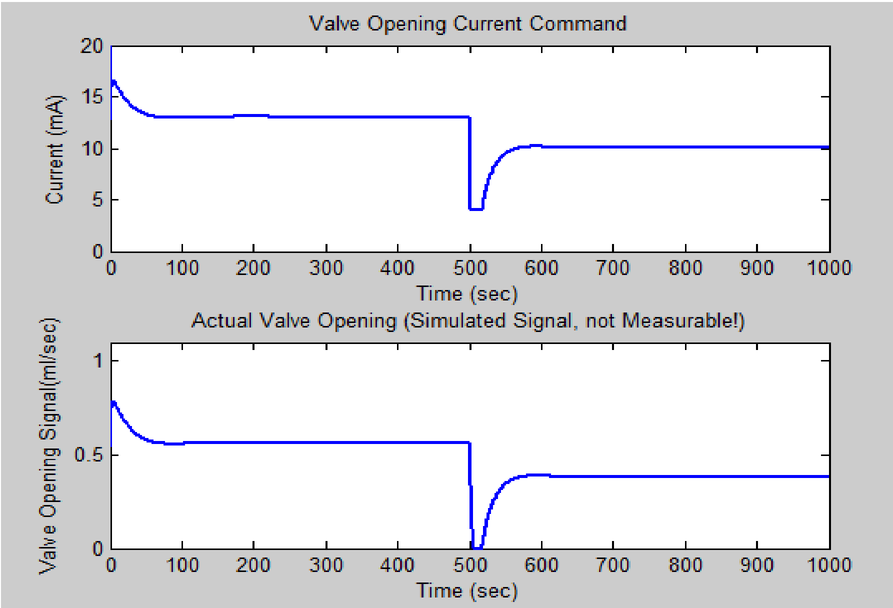

Fig. 4 Valve Opening Signals

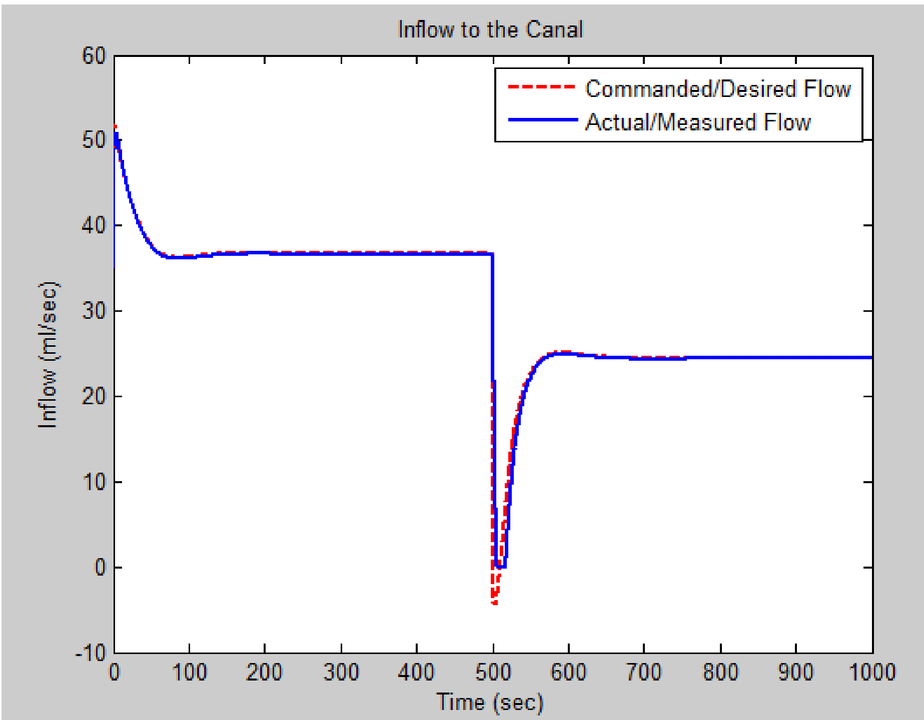

Fig. 5 Inflow to the Canal

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Fig. 5 shows the graph of inflow to the canal (ml/s) Vs time (sec). Depending upon the valve opening command the water flows to the canal that gives the graph inflow to the canal. This inflow signal is given back to controller as a feedback measured flow signal.

VI.CONCLUSION

The implemented hierarchical PI control of an irrigation canal is found to be feasible and cost effective for optimizing water resources for agriculture. The automated irrigation system developed proves that the use of water can be diminished and the irrigation system can be adjusted to a variety of specific crop needs and requires minimum maintenance. We have presented a simulation-based case study using a numerical model of a real canal to illustrate the approaches and, in particular, to analyze the performance obtained by the PI controller and the subsystems of the Simulink model. In the current implementation of simulation, it is assumed that the head gate access is continuous. However the head gate may away from the control room

Future work will include testing the hierarchical controller using different setups of the simulation and different scenarios on a real irrigation canal to analyze the performance of the controller. And also it includes the implementation of real time irrigation control algorithm using *supervision, control, and data acquisition* (SCADA) system.

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