

Lab VIEW Based Control of Water Distribution Networks

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Abstract - Water distribution networks comprise engineered hydraulic and hydrological components which deliver water of appropriate quality, pressure and quantity to consumers. Network modeling and computer based control is a critical part of designing and operating water distribution systems that are capable of serving communities reliably, efficiently, and safely. The availability of increasingly sophisticated and accessible models allows these goals to be realized more fully than ever before. In this work, the monitoring and computer control done is affected using Lab VIEW and associated Human Machine Interface (HMI). A level control using fuzzy logic is designed.

Index Terms— WDN, Lab VIEW, HMI, Control, Fuzzy Controller

I. INTRODUCTION

Water Distribution Networks comprise hydraulic and hydrological components which deliver water of appropriate quality, pressure and quantity to consumers. They are designed to satisfy water requirement for a combination of Domestic, Commercial, Industrial and Fire fighting purposes [1]. Broadly, there are two layouts of WDNs: Looped (or grid) configuration and branched configuration. Branched networks are used for small capacity community supplies while looped distribution networks can supply from more than one direction with improved reliability [2,3]. The network can also be classified as pumped or gravity driven. In a pumped system, the driving force to overcome friction or gravity is generated using motor driven pumps. In gravity flow systems, water is stored in elevated reservoirs and flows under gravity. Both networks are considered in this contribution. Network controlling and monitoring can be done through Lab VIEW software by interfacing appropriate sensors. Controller for level measurement is by a Fuzzy controller with corresponding membership functions.

II. SYSTEM DESCRIPTION

A typical WDN consist of several reservoirs, treatment plants, control valves, pumping stations and level measurement equipments. It must provide 24x7

water supplies when there is sufficient amount of water available. In this work, optimum control and monitoring of WDNs is demonstrated through a scaled down version of typical WDNs. The scaled down version is developed in such a way that it reflects the complexities and dynamics of real world WDN[3]. It is built using pipe elements of ID 4-20mm, appropriate actuators and sensors. The design and necessary flow conditions were verified using hydraulic analysis done in EPANET software. The time factor is scaled down to 24 Minutes, so that, each minute corresponds to 1 hour of water supply in real time network. The topology of sub networks and their demand patterns are reconfigurable.

The network has four Over Head tanks each of 100 l capacity, supplying water to four sub networks each consisting of 5 demand points. The sub networks consists of ON/OFF solenoid valves at the ends to control the flow and pressure sensors are used to measure the pressure available near the demand points. Four continuous control valves are provided to regulate the flow into each network. Four inline ultrasonic flow meters are used to measure the flow into each network. Water from the demand points is collected in storage vessels and the consumption is monitored through level sensors placed in them.

Each of the four sub network, which is placed at a height of one meter from the ground level. The Over Head Tanks for each network are placed at a height of 4m from ground level.

All the Monitoring and control will be done through Lab VIEW by interfacing all the sensors and actuators to PC using NI USB cDAQ.

III. MONITORING AND CONTROL

A Lab VIEW program serves as the human machine interface. Fig 1 indicates the Front panel of WDN Lab VIEW Simulation. The main P&ID is drawn in Edraw Max software and imported into the Lab VIEW using Customized Control option.

From this front panel, the user will be able to know:

- i. The state of pumping motor(ON/OFF)
- ii. Ability to directly stop the motor if it is needed
- iii. The state of valves
- iv. The amount of water available in the OHT and demand points
- v. Flow rate in pipe
- vi. Pressure at the demand point

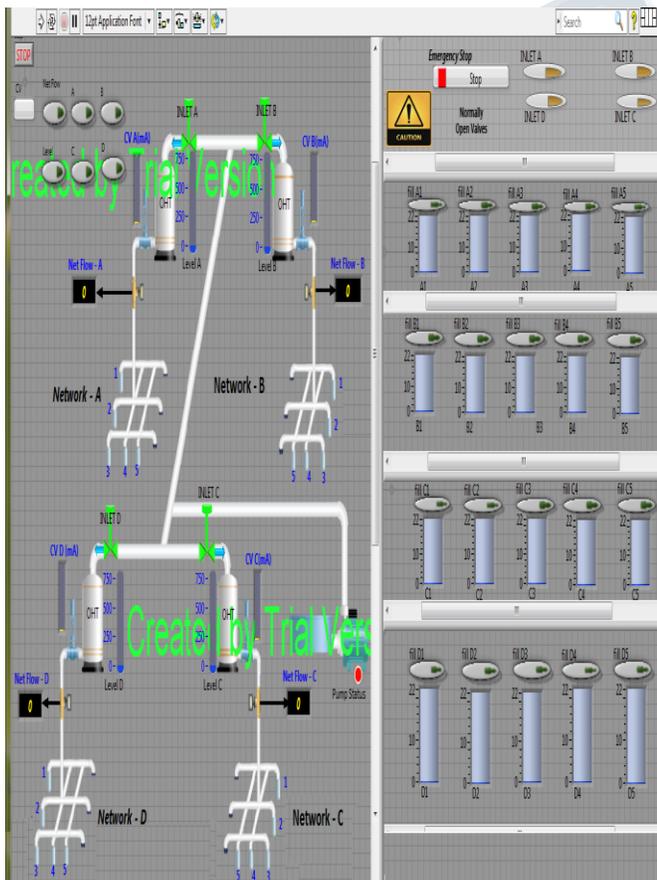


Fig 1 Lab VIEW front panel (HMI)

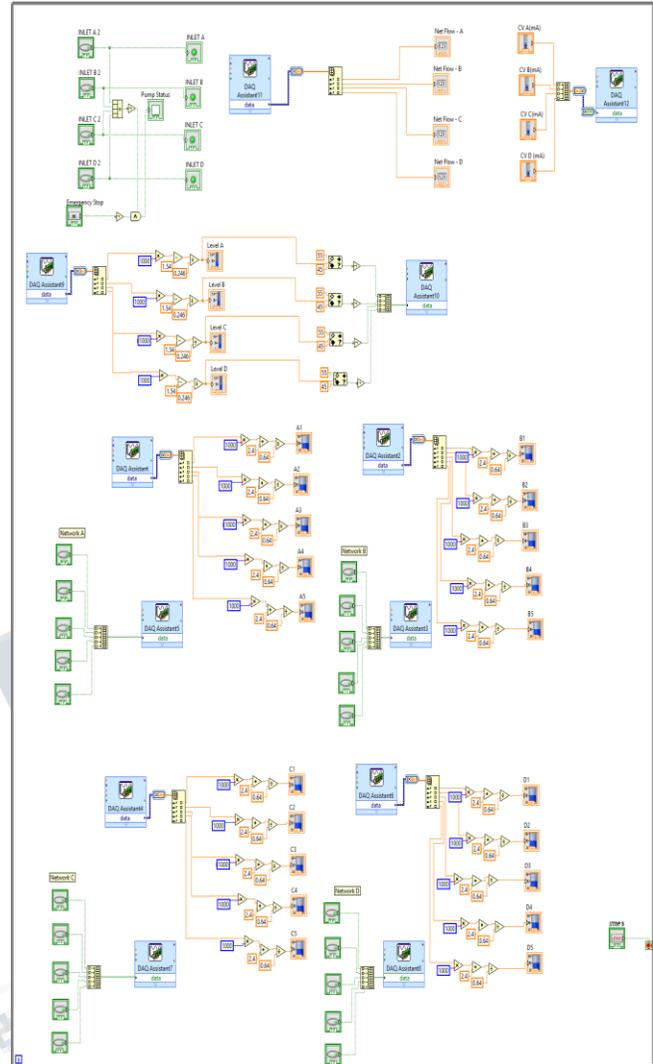


Fig 2 Lab VIEW Block Diagram

The Data Acquisition module (DAQ Assistant in Lab VIEW) is used to interface the sensors and transducers to PC. Fig 2 shows the monitoring strategy done using the software.

The controller used here is a fuzzy controller with appropriate membership function.

Fuzzy logic controller is to be used for time varying and non linear processes this type of controller which is designed based on human intelligence. It mimics the control actions of human operator. [4]

A Fuzzy logic controller consists of mainly three parts; Fuzzification, Inference engine and Defuzzification. The measured variable from a plant is normally in numerical form. So the fuzzification is used

to convert this numerical variable into linguistic form. In Inference engine IF-THEN rules are framed. Finally, the linguistic variables are converted to numerical form and given to the plant. This process is known as defuzzification. The proposed consist of twelve fuzzy controllers in which five are having Two input one output system (MISO) and seven are having Single input Single Output System (SISO). In two input fuzzy controller, Level is denoted as one input and position of Control valve as the other while valve (ON/OFF valve position) is the output. The membership functions which are using here is triangular membership function for both inputs and output[5,6].

IV. DESIGNING OF FUZZY LOGIC CONTROLLER

a. Fuzzy System Designer

The proposed system consists of two types of fuzzy controllers, one is SISO system and the other is MISO system. Two inputs for the MISO fuzzy controller (Level and Control Valve position) and the output (Valve ON/OFF) are applied to the Fuzzy Designer system.

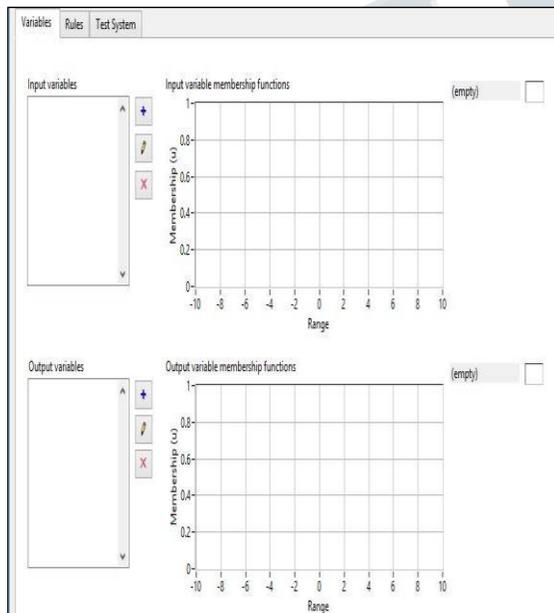


Fig 3 Fuzzy Designer System

Four type of design used in the network are

- i. Fuzzy controller for ON/OFF Solenoid Valve OHT
- ii. Fuzzy controller for ON/OFF Solenoid Valve Demand point

iii. Fuzzy controller for Drain Valve (ON/OFF Type) at Demand point

iv. Fuzzy controller for Control Valve at OHT

Number of instruments is included here for level measurement and control. They are OHT (1), Demand point tanks (5), Ultrasonic distance sensors (6); ON/OFF Solenoid Valves (11), Control valve (Globe Type 1) etc.

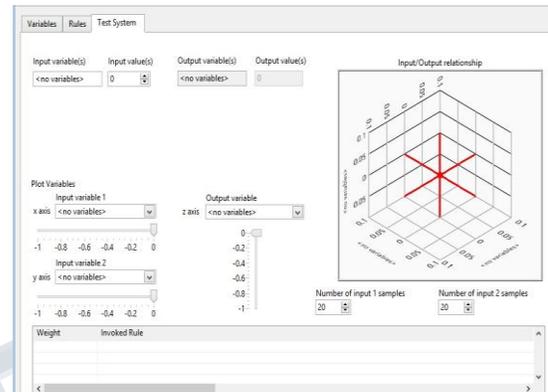


Fig 4 Fuzzy Test system

b. Membership Function Editor

The Membership Function editor is a tool that displays and edits all of the membership functions associated with all of the input and output variables for the entire system [6]. The labels assigned to each MFs are Level, CVoutput, CV, Drain and Valve.

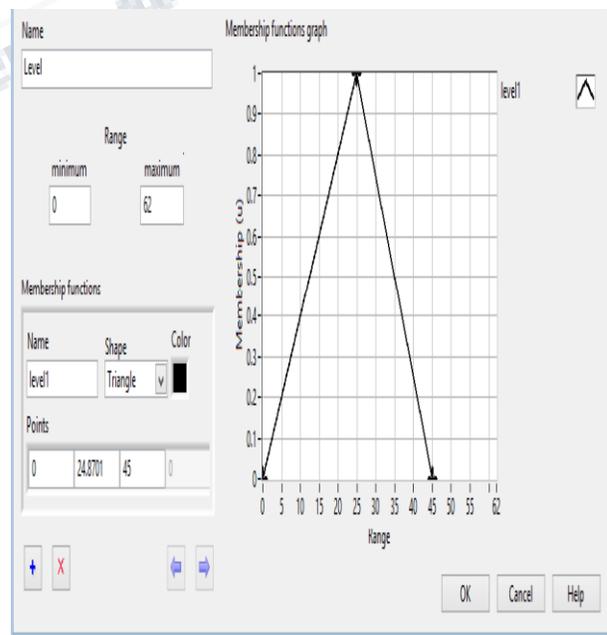


Fig 5 Membership Function Editor

a) Fuzzy Set Characterizing Input

i. Level [Range (0 to 62)] at OHT

Table I Crisp Range table for Level

Fuzzy Variable	MF Used	Crisp input Range
level1	Triangular	[0 27.5 45]
level2	Triangular	[45 50 55]
level3	Triangular	[55 58.5 62]

ii. Level [Range (0 to 30)] at demand point

Table II Crisp Range table for Level

Fuzzy Variable	MF Used	Crisp input Range
level1	Triangular	[0 5 10]
level2	Triangular	[10 17.5 25]
level3	Triangular	[25 27.5 30]

iii. CV [Range (0 to 1)] at demand point

Table III Crisp Range table for CV

Fuzzy Variable	MF Used	Crisp input Range
CVfull	Triangular	[1 1 1]
CV50	Triangular	[0.5 0.5 0.5]
CV0	Triangular	[0 0 0]

b) Fuzzy Set Characterizing Output

i. Valve [Range (0 to 1)] at OHT

Table IV Crisp Range table for Valve

Fuzzy Variable	MF Used	Crisp output Range
ON	Triangular	[1 1 1]
OFF	Triangular	[0 0 0]

ii. Valve [Range (0 to 1)] at demand point

Table V Crisp Range table for Valve

Fuzzy Variable	MF Used	Crisp output Range
ON	Triangular	[1 1 1]

OFF	Triangular	[0 0 0]
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iii. CV [Range (0 to 1)] at OHT

Table VI Crisp Range table for CV

Fuzzy Variable	MF Used	Crisp output Range
CVfull	Triangular	[1 1 1]
CV50	Triangular	[0.5 0.5 0.5]
CV0	Triangular	[0 0 0]

V. RULE EDITOR

Constructing rules using Graphical Rule editor is the final step of Controller design. Based on the input output variables with the fuzzy system designer, allows to create rule statements automatically [7, 8].

a) Rules for Controller at OHT

- i. If (Level is level1) then (Valve is OFF) (1).
- ii. If (Level is level2) then (Valve is OFF) (1).
- iii. If (Level is level3) then (Valve is ON) (1).

b) Rules for Controller at OHT (CV side)

- i. If (Level is level1) then (CV is CV0) (1).
- ii. If (Level is level2) then (CV is CV50) (1).
- iii. If (Level is level3) then (CV is CVfull) (1).

c) Rules for Controller at OHT at demand points

- i. If (Level is level1) and (CV is CV0) then (Valve is OFF) (1).
- ii. If (Level is level2) and (CV is CV0) then (Valve is OFF) (1).
- iii. If (Level is level3) and (CV is CV0) then (Valve is OFF) (1).
- iv. If (Level is level1) and (CV is CV50) then (Valve is ON) (2).
- v. If (Level is level2) and (CV is CV50) then (Valve is ON) (2).
- vi. If (Level is level3) and (CV is CV50) then (Valve is OFF) (2).
- vii. If (Level is level1) and (CV is CVfull) then (Valve is ON) (3).
- viii. If (Level is level2) and (CV is CVfull) then (Valve is ON) (3).
- ix. If (Level is level3) and (CV is CVfull) then (Valve is OFF) (3).

d) Rules for Controller at demand points (Drain side)

- i. If (Level is level1) then (Drain is OFF) (1).
- ii. If (Level is level2) then (Drain is OFF) (1).
- iii. If (Level is level3) then (Drain is ON) (1).

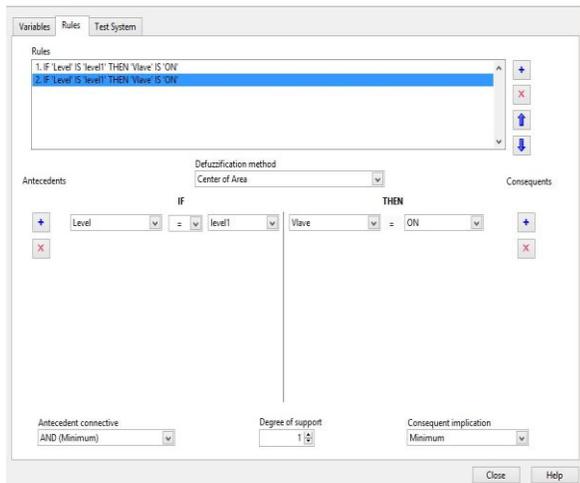


Fig 6 Fuzzy rules editor

VI. SIMULATION BLOCK DIAGRAM

Simulation block diagram of the complete system is shown in the Figure 7. In this we control the water level of the system with the help of Fuzzy Logic Controllers in the Lab VIEW simulation. Inputs are given in the valve; these are control the source flow. The valve is connected to the fuzzy controller for controlling outflow[9].

In this system, water level inside the Over Head Tank is monitored by using ultrasonic distance sensor. If the water level in the tank is below a particular value (below 45 cm), the valve will be turned ON and above a particular value (above 55cm), and it will be turned OFF. Similarly the water level inside the demand point also monitored by Ultrasonic distance sensors. Here the level is above 25 cm, the valve will be turned OFF and below 25 cm it will be turned ON.

From Lab VIEW, the user has the ability to

- i. Infer Current state of the pump
- ii. Directly stop the motor if needed
- iii. Infer the amount of water available in both OHT and Demand Points
- iv. Infer Flow Rates

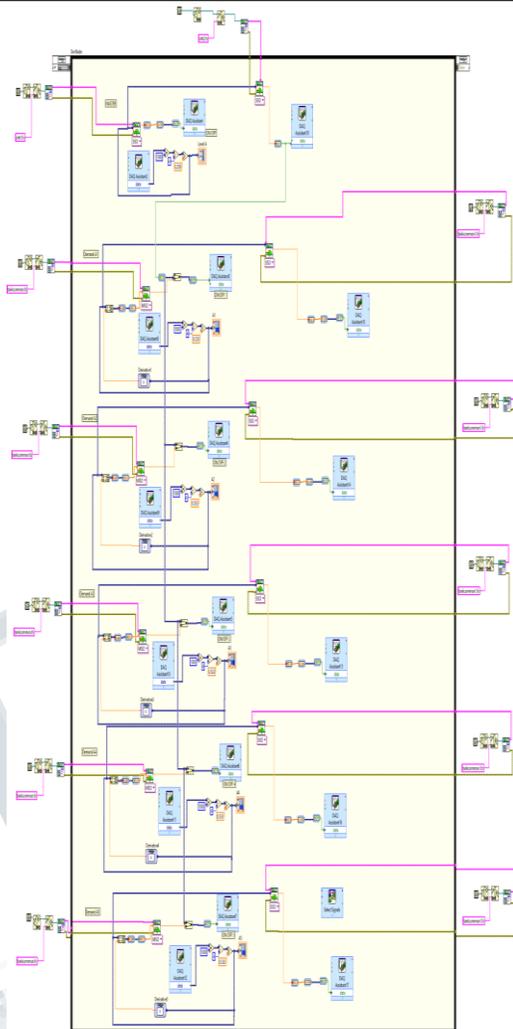


Fig 7 Lab VIEW block Diagram - Fuzzy Controller

VII. CONCLUSION

The paper has described the design and implementation of Water Distribution Network in Lab VIEW with the help of Fuzzy logic Controller.

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