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Research Article

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Intelligent feed forward control of chemical dosing pump using pulse width modulation

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ABSTRACT

This research aims to develop a control scheme for automatic control of dosing pump for a laboratory based water treatment plant. The chemical dosing pump delivers the alum with different flow rates depending on the dosage requirement for the laboratory based water treatment plant. The alum flow rate is controlled by an intelligent controller, which includes a neural network and a pulse width modulator. The intelligent controller is a steady state feed forward controller. The result shows that the steady state feed forward controller will be able to control the flow rate accurately.

Key words: chemical dosing,feed forward controller, pulse width modulation, water treatment plant.

INTRODUCTION

The purpose of dosage control is to reduce the turbidity of the drinking water below accepted standard. Conventional controllers like Proportional Integral and Derivative controllers cannot be used because of the nature of water treatment process. Alum dosage reduces the turbidity of the water. At the same time excess alum dosage leads to health hazards. Hence the conventional feedback control is not suggested in this paper. In dosage control systems, especially in the water treatment process feed forward controller is preferred[1].The quality of the water is to be measured at the input side of the water treatment plant and the desired amount of alum must be added to take corrective action.Normally alum is available in the form of solid. Controlling the flow rateof solid alum is difficult. Hence saturated solution of alum is prepared by mixing known quantity of alum with known quantity of distilled water. This saturated solution is fed to the water treatment plant by a pump. As per the laboratory based water treatment plant requirement the pump must be operated between 2.37×10^{-7} to 2.13×10^{-6} cubic meter per second. The pump speed is controlled by pulse width modulation [2]. This paper focuses only on the development of an intelligent control of the alum dosing pump using a steady state feed forward controller, which uses a neural network and pulse width modulator.

EXPERIMENTAL SECTION

The pilot plant for the water treatment process developed in the laboratory provides the facility for the design and testing of alum dosage controller. Pilot plant includes the three major water treatment processes[3] coagulation, flocculation, sedimentation and a dosing tank with pump. The pump used for alum dosage control is Windshield Washer Pump. The dosage is fed to the coagulation tank. Coagulation is a fast mixing process where the alum is mixed with the suspended solids to produce flocs [4]. The next process is a slow mixing process called flocculation where the flocs combine together and form larger flocs. The last process is sedimentation which removes the larger flocs by gravity method. The option for removing sludge is given in sedimentation process.

Dosing Control

Feed forward controller is suitable for water treatment process since it is a very slow system[5]. The changes in the treated water turbidity from the above mentioned laboratory based water treatment plant for a particular alum dosage can be observed only after one and a half hours. The controller cannot wait for a long time to take decision, hence the changes in the input water quality parameters are measured and the required alum dosage is added at the input raw water immediately.

Pulse Width Modulation

Open loop control is implemented for the alum dosing system. Pulse width modulation is used by most of the open loop control systems. The relationship between the duty cycle and controlled variable is used for such control [6]. Pulsewidth modulation is a commonly used technique for controlling the electrical devices. The control action is derived by controlling the average value of voltage fed to the pump. The power supplied to the pump is varied by the duty cycle. Power supplied to the load is increased by keeping the switch in on position for a long period compared to the off period andthe power supplied to the load is decreased by keeping the switch in off position for a long period compared to the on period. Duty cycle is expressed in percentage, 100% being fully on and 0% being fully off. The alum flow rate through the pump is decided by the duty cycle. The switching frequency chosen is 1000 Hz. The Pulse width modulation (PWM) controller output is depicted in Figure 1. IC L298 is used to drive the pump for the desired flow rate. IC L298 acts as a switch between supply and the load. The pump is driven by 9 V DC.

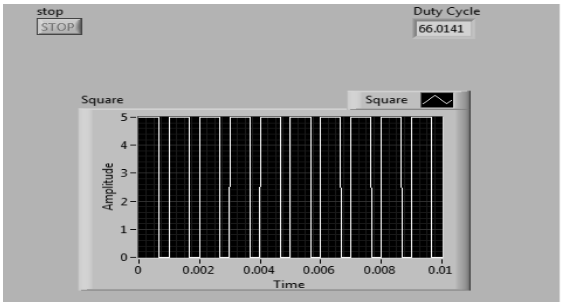

Fig1: PWM Controller output

Calculation of Dosage Flow Rate

Table 1: Alum flow rate requirement

Sl. No	Alum Dosage required for 0.001 cubic meter of raw water(kg)	Liquid Alum Dosage required for 0.001 cubic meter of raw water (cubic meter)	Liquid Alum Dosage required for 0.00333 cubic meter of raw water (cubic meter)	Liquid Alum Flow Rate(cubic meter per second)
1	0.0094	0.0000282	9.3906×10^{-7}	9.3906×10^{-7}
2	0.011	0.000033	1.0989×10^{-6}	1.0989×10^{-6}
3	0.0108	0.0000324	1.07892×10^{-6}	1.07892×10^{-6}
4	0.008	0.000024	7.992×10^{-7}	7.992×10^{-7}
5	0.0104	0.0000312	1.03896×10^{-6}	1.03896×10^{-6}

The alum dosage required to treat 0.001 cubic meter was found using Jar Test [8]. The Jar test was repeated to find the alum dosages for many samples. These data were fed into the artificial intelligence network to decide the required alum dosage for the raw water [9]. The raw water flow rate is fixed at $3.33\times10^{-5}m^3$/sec. The amount of alum required for the water treatment process is calculated using artificial intelligence. Alum dosage is prepared by dissolving 3 kg of alum into 9×10^{-3} m^3 of distilled water. Table 1 shows the dosing flow rate for different alum dosages. Only five cases of alum dosage requirement are shown in table. Simple arithmetic calculations are used to find the flow rate using LabVIEW.

Experimental Analysis

The manipulated variable in the dosage control system is duty cycle of the pulse width modulation. Experiment was conducted to find the flow rate of the pump for various duty cycles and the results were tabulated in table 2. The minimum flow rate is $2.37\times10^{-7}m^3$/sec and the maximum flow rate is $2.1349\times10^{-6}m^3$/sec. The minimum and the maximum flow rates are obtained at 41% and 100% duty cycles respectively. The data collected from the experiment are used for the development of intelligent controller.

Table 2: Flow rate of Alum for various Duty Cycles

Duty cycle (%)	Flow Rate (Cubic metre/ second)	Duty cycle (%)	Flow Rate (Cubic metre/ second)	Duty cycle (%)	Flow Rate (Cubic metre/ second)
41	0.000000237	61	0.0000008197	81	0. 0000015442
42	0.0000002463	62	0.0000008475	82	0. 0000015625
43	0.0000002564	63	0.0000008772	83	0. 0000015679
44	0.0000002717	64	0.0000009091	84	0. 0000015743
45	0. 0000002941	65	0.0000009434	85	0. 0000015803
46	0. 0000003185	66	0.0000009804	86	0.0000016
47	0.0000003546	67	0.0000010204	87	0.0000016297
48	0.0000003788	68	0.0000010638	88	0.0000016529
49	0.0000004065	69	0.0000011111	89	0.0000017241
50	0. 000000431	70	0.0000011628	90	0.0000017409
51	0.0000004673	71	0.0000011905	91	0.0000017756
52	0. 000000495	72	0.0000012195	92	0.0000018215
53	0.0000005319	73	0.00000125	93	0.0000018389
54	0.0000005682	74	0.0000012821	94	0.0000018776
55	0.0000006024	75	0.0000013158	95	0.0000019055
56	0.0000006494	76	0.0000013514	96	0.000001947
57	0.0000006849	77	0.0000013889	97	0.0000019701
58	0.0000007246	78	0.0000014286	98	0.0000020559
59	0.0000007576	79	0.0000014706	99	0.0000020358
60	0.0000007937	80	0. 0000015152	100	0.0000021349

Flow rate is measured using a standard jar. The pump is switched on with any one duty cycle and the process fluid is allowed to fill the standard jar. The time taken to fill one liter of process fluid in the standard jar is found using a timer. The same procedure is continued to find the flow rate of each duty cycle. This method gives the flow rate unit as liter per second which is converted to the SI unit cubic meter per second.

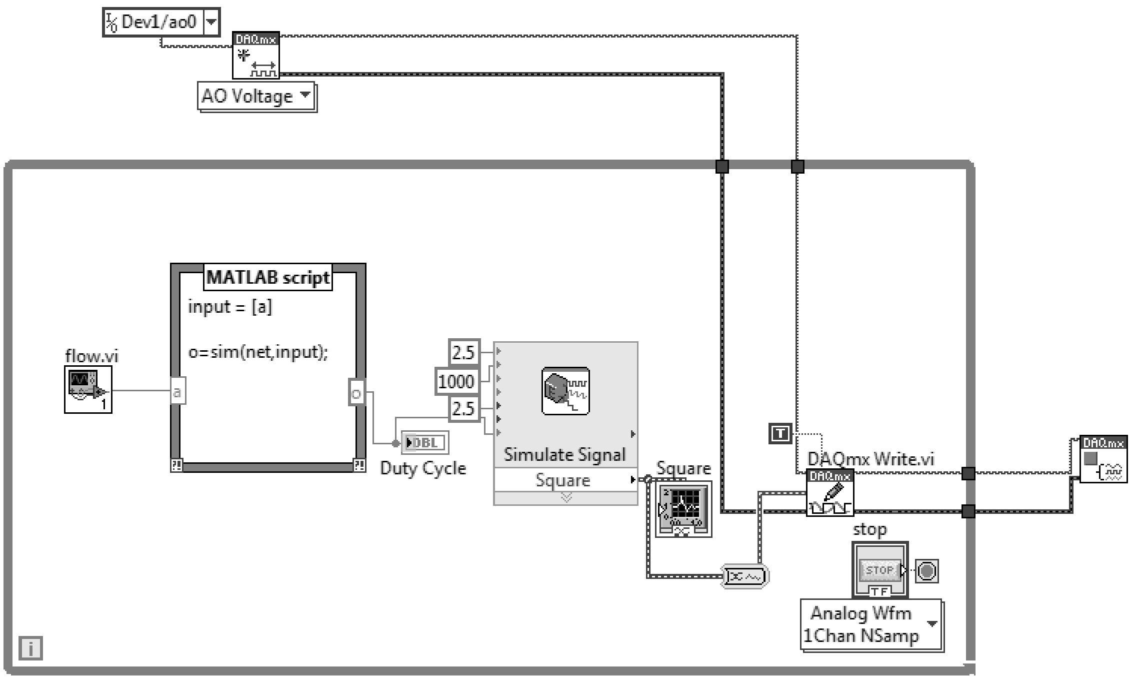

Fig2: Implementation of Intelligent Dosing Control System using LabVIEW

Development of Intelligent Controller

Neural network is suitable for predictive control [9, 10].Here neural network is used as an intelligent controller. Sixty data are used in neural network development process. Among the sixty data 70% of data is used for training, 15% data is used for testing and 15% of data are used for validation. The network is trained with levenberg-marquardtbackpropagation algorithm [11, 12]. Since this research concentrates on the static steady state response of dosage control, feed forward [13, 14] neural network is chosen.

The network is developed using nftool available in MATLAB. Real time control is implemented with the help of LabVIEW. Neural network developed by the MATLAB is invoked by LabVIEW MATLAB script. Neural network is used to decide the duty cycle of the PWM controller [15]. The input to the neural network controller is the flow rate of alum, based on the alum flow rate it predicts the required duty cycle for the PWM controller. The predicted duty cycle is the input to PWM controller. Thus the PWM controller controls the dosing pump with the desired flow rate. The real time implementation is shown in the Figure 2. The dosing pump is interfaced with the LabVIEW through NI myDAQ which is an USB based data acquisition card.

RESULTS AND DISCUSSION

The position of the dosing tank from the coagulation process tank is the major constraint in the design process. The flow rate of the pump varies depending on the distance between the dosing tank and the coagulation process tank. Based on various trials the optimum distance between the dosing tank and the coagulation process tank is found. The minimum and the maximum flow rates are also the constraints considered for the optimum distance between the dosing tank and the coagulation tank. The task given to the intelligent controller is to decide duty cycle of the PWM controller. The intelligent controller is able to predict the duty cycle of PWM controller accurately.

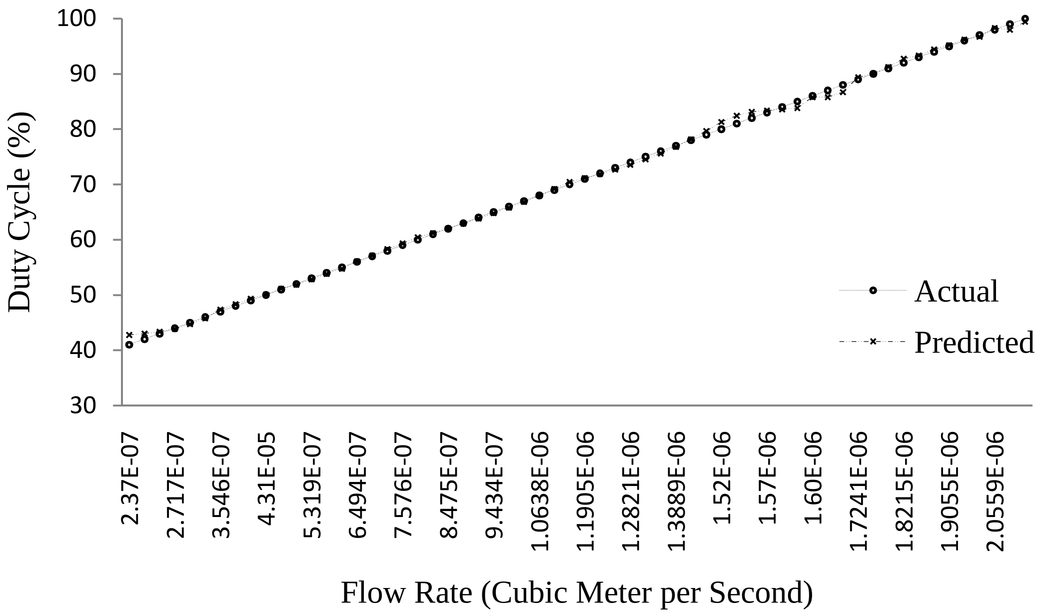

Fig 3: Actual Versus Predicted Duty Cycle

Figure 3 shows the actual and the predicted duty cycles for various flow rates. The flow rate controller is able to predict the duty cycle very accurately. The root means square error for the actual and the predicted duty cycle is 0.064 and the correlation coefficient is 0.999. Hence both the actual and the predicted duty cycles are almost same.

CONCLUSION

A small scale dosing system normally uses a dosing pump or metering pump for controlling the dosage. The dosage rate must be set by the operator. The proposed intelligent controller ensures the online monitoring and control of alum dosage for the laboratory based water treatment plant. The intelligent steady state feed forward controller is developed and tested with the existing laboratory based water treatment plant. The steady state performance of the control system is only considered because of the enormous time required for the treatment. The alum dosage is fixed based on the inlet raw water quality.The plant is interfaced with LabVIEW for the dosage control. This facility enables the automatic control of alum dosage.

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