Fuzzy Logic Based Flow Controller of Dam Gates

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Abstract—This paper presents the design and simulation of flow controller of dams gates using fuzzy logic based control system. A new way of controlling the opening and closing of dam gates has been proposed in this study. The system has been developed firstly in MATLAB using fuzzy logic Mamdani model and then the system is checked by developing a simple C language code using Microcontroller. Two input parameters have been selected like water level and water speed. The three membership functions to these parameters have been assigned. The one output parameter is selected as flow controller. Three membership functions are also assigned to the output. In this study the system works according to the rules defined in the fuzzy inference system. The simulation results are compared with the calculated results of mamdani formula. A pseudo code is developed from the rules defined in the FIS and code is generated in C language. The C language code is then burnt in the Atmel 89C51 microcontroller and a simple control circuit is developed to check the software results on practical basis. The basic concept of the study is that this system will show extreme response on extreme condition otherwise it will show normal results. When both inputs are in the higher (high water level and fast speed) region the output results will also be in the higher region (dam gates full open). This system showed great efficiency and robustness as it can be easily seen from the observations. This system is much different from the conventional systems as it involves simple microcontroller circuit.

Index Terms— Fuzzy logic, Dam gates, Flow controllerl, Membership functions, Fuzzy rule editor, Fuzzy inference system.

I INTRODUCTION

Life on earth began a long ago. Human beings used to live in jungles and used to hide in caves. Human being fed themselves by hunting animals and covered themselves by their skin. When the first human came on earth he did not even know how to cover himself, but by the time passed he discovered that he could cover himself by leaves of trees, he could himself by hunting the animals. In short man tried to learn how to live at this earth. He learnt how to survive in the extreme conditions. It was his fight for the survival which made him the most intelligent and powerful creature on the earth. The term survival of the fittest reminds us of very interesting creature dinosaurs but they also vanished and could not survive on earth, but it was human being who always tried to find the new way to feed himself and to cover himself. In fact humans have always struggled for the betterment of their life. Although humans were always passionate for finding the new ways of making their life comfortable, but for last few centuries' charismatic changes have occurred in the life of every single human being due the marvelous and miraculous inventions of science. The work of years was reduced to months, of months was reduced to days, of days was reduced to hours and of hours is reduced to minutes, seconds, and even to nano-seconds.It was all done due to the hard work of human beings. The new technologies now a day have changed the entire course of human life. Of that new technology many are not robust and have much room for error. The humans have built dams and artificial resorvoirs etc. to get water and energy from them. Dams are the major sources of hydro energy. Fuzzy logic is basically a flexible technique and is a numerical representation of system in which answer is just not only high or low, 0 or 1, ON or OFF and True or False. It is a free technique which is not bounded by any specific states. Let us take an example of thermally heated metal where value is not just only hot or cold but also between them, this system could be easily developed by using fuzzy logic as it can tell that some part of the metal is at normal temperature. The most common way of using fuzzy logic is to solve it through MATLAB software.

Bagis et al. described a to control the spillway gates of novel way to control the spillway gates of dams.The method they proposed was extremely different from the conventional way of controlling the flow controller spillway gates of dams.The controller they used was fuzzy proportional derivative which was based on evolutionary algorithm. The suyatem was found as robust controller was very indifference with the normal controller based on fuzzy logic.The main purpose of the controller was to provide a betterment in controlling the reservoir gates. Different hydrograph with the different magnitudes were used to simulate the purposed control system.The result provided by simulation indicated that the system is not even robust but also provide the accurat and proficient results. In fact the system was totally different from the common conventional system [1]. Lin et al. proposed an intelligent fuzzy logic system which whose basis was artificial neural network. It was a system which could be easily compared with the average used fuzzy system. The uniqueness of the system was its ability to take right decision on right time and right place. This fuzzy system with ability to take decisions could be based on techniques of machine learning. The structure could be easily made to learn the rules of fuzzy logic and could easily find the inputs and outputs. It was seen that by connecting the self-organized and supervised system the results taken were astonishing. The system designed was user friendly and could be easily understood by anyone. Two examples were used to explain the system rightly. Although the system had some resemblance with the conventional fuzzy system but in some ways it was quite different from it. The system was seen to be giving strong and proficient results [2].

Castro presented a work on the topic how does fuzzy logic is an approximation method and why it has an edge over other logics. He also described why does fuzzy logic shows great performance while other logics cannot do so. People mostly criticize the performance of fuzzy controller but in this work it has been proved that the fuzzy controller has great impact on daily life problems. It is basically a novel method. Fuzzy system uses linguistic based problem solving method. It has shown promising results as it is based on differentiable input fuzzification and output defuzzification. Castro has shown both quantitative and qualitative approach to these fundamental questions [3].Tang et al. proposed a fuzzy logic based system for creating genetic algorithm. He used a method in which genes were divided in to two different inputs. Fuzzy membership functions were used to define the parameters of inputs. Fuzzification was done on the input and rules were defined, then defuzzification was done on the output sides. Fuzzy logic based system is used due to its unique way of tackling complex and non-linear problems [4].Sakthivel et al. described a new way to control a liquid level in a spherical tank. The level of liquid in a spherical tank is an extremely non-linear quantity as the cross sectional area of spherical tank is also non-linear.It has highest level of variation.A black box mdel has been used to solve the problem of this system .The Normal PI controller's parameters are use in this system and its servo response is compared with that of fuzzy logic response.MATLAB is used for the real time implementation of this system. The FL controller gives the promising results and helps in solving this nonlinear problem [5].

Adhikary et al. 2012 studies the hydro power plant and reported on their secure and competent control by using fuzzy logic. The control of water is very tough under improper conditions. To tackle such problems fuzzy logic method is very important tool. Fuzzy logic is a rule based technique and also membership functions have a great impact on the performance and efficiency of a system. This paper describes the fuzzy logic based controller method for safe reservoir control of dams through spillway gates. For secure spillway gate control the fuzzy logic controller (FLC) system used two input variables i.e dam lake level and water inflow rate. The output is only single variable "openness of the spillway gate", and is controlled by (FLC). The main purpose of this control system is to discharge excess water level and received desired water level. The things that are too complex to be mathematically modeled, is very easy described with fuzzy logic controller (FLC). The other advantage of fuzzy logic is automation control because humans are forgettable. This work can be extended to develop a method for relating fuzzy logic linguistic variables [6]. Graham et al.1986 reported on fuzzy discovery and direct of a water fit. To set control rule is very important and necessary in fuzzy logic controller (FLC) for better results. At the end a comparison is made by checking the experimental and practical results. The technique is consisting of a set of a linguistic variable which can explained on a process control computer using fuzzy logic. By counting fuzzy model classification with fuzzy controller originated a fuzzy adaptive regulator. The fuzzy controller is utilized in various variables control system [7].

Bagis 2002 proposed to find out fuzzy link task with tabu search a function to manage method. In this paper there is a new methodology to select membership functions for a fuzzy logic controller with tabu search. Fuzzy logic controller is a quick system precise by linguistic reports based on rule or data based. If mathematical modeling is very complex or the system is non-linear or dependent on time, then we use fuzzy logic controller (FLC) to solve such kind of problems very effortlessly with effectiveness. In this research a new algorithm is presented i.e. tabu algorithm which is based on knowledge based system consist of data and rule base. Glover presented tabu search method which is a strong technique to solve dense problems. The results of tabu search algorithm can be adapted by changing the control parameters such as original results, tabu states, type of shift and active actions of a system [8]. Hasebe et al. 2002 reported on the reservoir operation by using fuzzy logic system. In this paper the technique of neural network is also applied. Dam is used for various-purpose like storage of water in demand for water and energy, balances for rise and fall in river water flow and to increase the rank of water. Fuzzy system is applied in competent way when only use of water and neural network is applied for flood control. Dam water level, rainfall, inflow, estimated inflows are the input components used in this paper. Storage and outflow are the output variables. Result explains there is a discrete variation in flood season and non-flood season, as in the case of flood. If key is used for storage then it explains better performance in non-flood season, and composition detection for the season of flood [9].

Karaboge et al. 2007 studies on scheming spillway entry of dams and reported on making a fuzzy logic controller with most advantageous laws. The water tank process is a very difficult and non-linear method. So a fuzzy logic controller is made with minimum rule number to solve such kind of problems. Fuzzy logic controller is made with the help of tabu search algorithm. TS technique is used to conclude outstanding regulation base of fuzzy controller. By using the TS technique, the function to presenting rule arrangement with the least amount of laws happens to consistent and better results are attained [10]. Bagis et al. 2004 reported on artificial neural networks and fuzzy logic based controlled of spillway entry of dams by using fuzzy logic controller. The neural network technique is also used in it. In this paper a very ample way is offered for calculating the spillway gates of dams during flood season. Artificial neural network is familiar work with nonlinear conditions. A controlled system is made with dissimilar situations of flood i.e what is the value of water when the flood is come. A comparison is made between the results of practical and theoretical. The performance shows that, it gives better results to control the spillway gate of dams by using neural network and fuzzy logic technique [11].

Chang et al. 2005 presented adaptive neuro - fuzzy conclusion system forecast in water reservoir. It is very important for the executive to verify the exact value of water in reservoir. A neuro- based fuzzy inference system was used to make the water level control system during floods and land sliding. In the reservoir of water level, this case is discussed and we obtain the proficient outcomes. Reservoir is basically a place where we collect or store something. Water reservoir is used for storing water during normal or dangerous circumstances. When the level of water is very high in the case of flood, then to make the best use of water is very important. A neuro fuzzy inference system is used to control the level of water reservoir. In this, we used two inputs 'a', 'b' and one output 'c'. Four rules are made as there are two inputs. In general, ANFIS model presented accurate and efficient prediction of water level for next three time steps, where the value of correlation coefficients (CC) are very close to unity larger than 0.99. By using fuzzy inference system dealt with complex inputs and output, we get a useful guide for the operations of flood control [12]. Wu et al. 2004 studied on a type-2 fuzzy logic controller for water intensity procedure. A genetic algorithm is used in a type-2 fuzzy logic controller to control a liquid-level process. A two-step process is used to make the type-2 fuzzy logic controller. In a first process, the parameters of a type -1 fuzzy logic controller are modified by using the process of genetic algorithm. In a second step process, footprint of uncertainty is involved by clearing the fuzzy input set. The result shows that the type-2 fuzzy logic controller meet with the complexity of plant and can handle the uncertainty better than its type-1 counterpart. Fuzzy logic is a flexible logic system whose values are approximate instead of exact. Fuzzy logic controller use linguistic '' If, Then" rules that can be made with the knowledge of experts in relevant field. FLC's are knowledge based controllers [13].

II DESIGN METHODOLOGY

A Designing in MATLAB

Fuzzy logic control system in FIS editor could be assigned by several numbers of inputs but here it has two inputs and each input has three (mfs) membership functions. The ranges should be selected according to the desired values of input (mfs) and output (mfs) , Here values of inputs and output has been taken(0-1 units) for both and shown in table 1.

The figure 1 shows that how the common regions have been differentiated. The first overlapped region of the range 0 to 0.5 and 0 to 1 is called Region 1 and second overlapped region of range 0 to 1 and 0.5 to 1 is called Region 2. It is same for the Water speed input. The calculations have been taken according to this regional division.

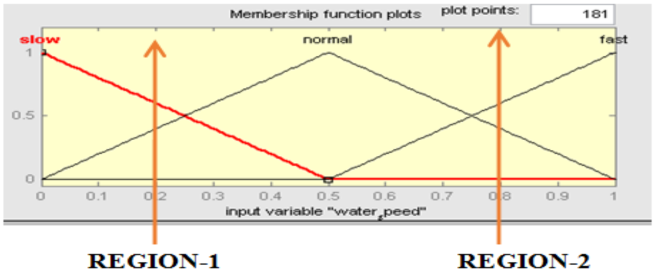

Figure 1 Division of the regions

In designing of this system different rules have been established for the better result. The rules involve the simple If and Then statement and the AND logic.

Table 1 Ranges selected for inputs and outputs

Membership functions	Ranges (units)	Input(1) Water level	Input(2) Water Speed	Output Flow Controller
mf1	0-0.5	High level(HL)	Slow(S)	CLOSED (C)
mf2	0-1	Normal level(NL)	Normal(N)	Normal Opened (N_O)
mf3	0.5-1	Low level(LL)	Fast(F)	Full Opened(F_O)

Table 2 Rules for the inputs and output

Rule No.	IF Water level	IF Water speed	Then Flow control
1	HL	S	N_O
2	HL	N	N_O
3	HL	F	F_O
4	NL	S	N_O
5	NL	N	N_O
6	NL	F	N_O
7	LL	F	N_O
8	LL	N	N_O
9	LL	S	C

The figure 2 and 3 shows the rule viewer graph of the system designed.

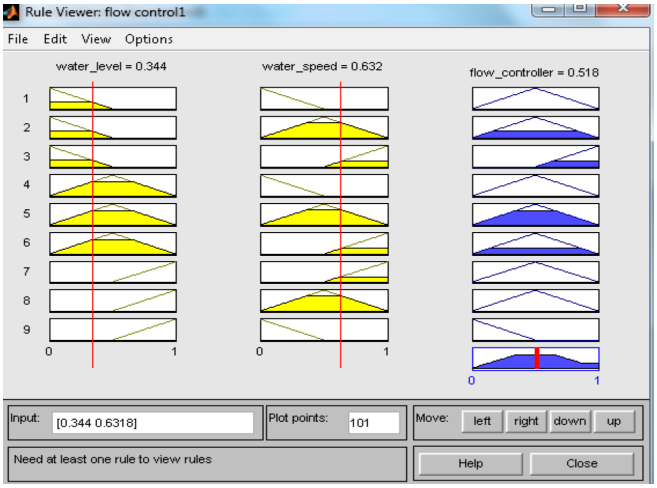

Figure 2 Results when water level is in region 1 and water speed is in region 2

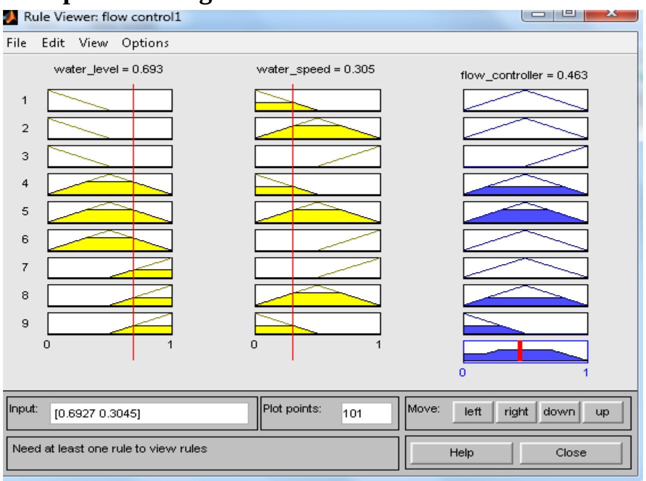

Figure 3 Results when water level is in region 2 and water speed is in region 1

The figures 4 and 5 show the surface viewer graph .

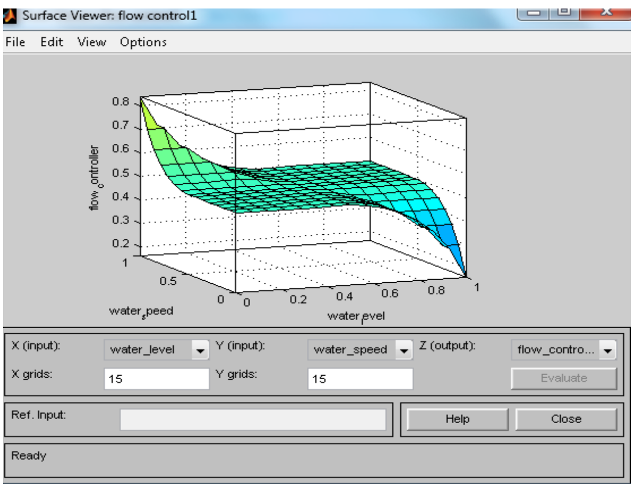

Figure 4 Surface graph between inputs and output

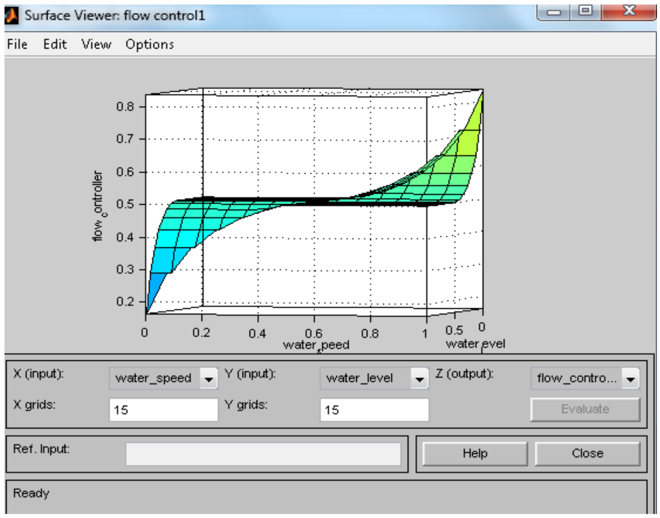

Figure 5 Surface graph between inputs and output

B Algorithm design for Flow Controller System

The input and output values are given below:

Water level is in Region 1= 0.344; Water speed is in Region 2= 0.632 and Flow controller tendency is Towards Full Opened Mf= 0.518 Water level the 1st input of the system; whose value lays in Region 1 in MF graphs. mfs are= High level (HL) and Normal level (NL).The mfs f1 and f2 for these values are:

f1= (0.5-0.344)/0.5 = 0.312

f2 =1- f1=1-0.312=0.688

Water speed the 2nd input parameter for the system; whose value lays in Region 2 of MF graphs. mfs are: Normal (N),Fast (F).The mfs f3 and f4 for these values are:

f3=(1-0.632)/1 = 0.368

f4 =1- f3=1-0.368=0.632

Singleton values for this system are given in table 3.

Table 3 Used for singleton values

Rule No.	Water Level	Water Speed	Flow control	Singleton Values
Ra	**HL**	**N**	N_O	**0.5**
Rb	**HL**	**F**	**F_O**	**1**
Rc	**NL**	**N**	N_O	**0.5**
Rd	**NL**	**F**	N_O	**0.5**

Water level is in Region 2= 0.693; Water speed is in Region 1= 0.305and Flow controller tendency is Towards Closed Mf = 0.463 .Water level the 1st input of the system; whose value lays in Region 1 in MF graphs. mfs are= Normal level (NL) and Low Level (LL).The mfs f1 and f2 for these values are f1= (1-0.693)/1 = 0.307

f2 =1- f1=1-0.312=0.693

Water speed the 2nd input parameter for the system; whose

value lays in Region 2 of MF graphs. mfs are: Slow (S) and Normal (N). The mfs f3 and f4 for these values are f3=(0.5-0.305)/0.5 = 0.39
f4 =1- f3=1-0.39=0.61
Table 5 shows the singleton values for this system:

Table 4 shows the singleton values

Rule No.	Water Level	Water Speed	Flow control	Singleton Values
Ra	**NL**	**S**	N_O	**0.5**
Rb	**NL**	**N**	**N_O**	**0.5**
Rc	**LL**	**S**	C	**0**
Rd	**LL**	**N**	N_O	**0.5**

III RESULTS AND DISCUSSIONS

Fuzzy logic (FL) based control system is being proposed here for the flow controller of water in Dams etc. The given system contains FL controller which has two inputs (water level, water speed) and 1 output Flow controller.AND logic has been used here. The Mamdani's model is used here the results of whom are given below:

Table 5 shows the rules corresponding to the mfs

Rule No.	Membership Function
Ra	**f1^f3=0.312**
Rb	**f1^f4=0.312**
Rd	**f2^f3=0.368**
Rd	**f2^f4=0.632**

A Calculations using the Mamdani's Formula

By using the formula for Mamdani'model output is calculated for both the conditions as
Water level is in Region 1=High Level= 0.344; Water speed is in Region 2=Fast = 0.632
And Flow controller tendency is Towards Full Opened
Mf= 0.518Where Ri are rules of table 4 and Si are singleton values of table 3.Here singleton values corresponds to 3 different variables of Flow Controller i.e Closed=0, Normal Opened=0.5 and Full Opened=1.
Hence Σ Si * Ri = S0 * Ra + S1 * Rb+ S2 * Rc+ S3* Rd =0.5*0.312+1*0.312+0.5*0.368+0.5*0.632=0.156+0.312+0.184+0.316=0.968
ΣRi = Ra + Rb + Rc + Rd = 0.312+0.312+0.368+0.632 =1.624
Flow controller = [ΣRi *Si / ΣRi] = 0.968/ 1.624 = 0.596
MATLAB SIMULATION VALUE= 0.518
CALCULATED VALUE= 0.596
Difference= 0.596-0.518 = 0.078
The tendency of the system lies in the region of Full Opened of mf of Output.

Table 6 shows the rules corresponding to the mfs

Rule No.	Membership Function
Ro	**f1^f3=0.307**
R1	**f1^f4=0.307**
R2	**f2^f3=0.39**
R3	**f2^f4=0.61**

Water level is in Region 2=Low Level= 0.693; Water speed is in Region 1=Slow= 0.305 and Flow controller tendency is Towards Closed Mf = 0.463 Where Ri are rules of table 4 and Si are singleton values of table 3.Here singleton values corresponds to 3 different variables of Flow Controller i.e Closed=0, Normal Opened=0.5 and Full Opened=1.
Hence Σ Si * Ri = S0 * Ra + S1 * Rb+ S2 * Rc+ S3* Rd =0.5*0.307+0.5*0.307+0*0.39+0.5*0.61=0.1535+0.1535+0+0.305 = 0.612
ΣRi = Ra + Rb + Rc + Rd = 0.307+0.307+0.39+0.61 = 1.614
Flow controller = [ΣRi *Si / ΣRi] = 0.612/ 1.614 = 0.379
MATLAB SIMULATION VALUE= 0.463
CALCULATED VALUE= 0.379
Difference= 0.463-0.379 = 0.084
The tendency of the system lies in the region of Closed of mf of Output.

B Observations

Using all the simulated and calculated results the following observations have been made which tell the robustness of the system.Water level is in Region 1=High Level= 0.344; Water speed is in Region 2=Fast = 0.632 and Flow controller tendency is Towards Full Opened Mf= 0.518

Table 7 Frest observations

Sr. No	Observation	Results
1.	**MATLAB Simulation Value**	**0.518**
2.	Design Value	**0.596**
3.	Difference	**0..078**

Water level is in Region 2=Low Level= 0.693; Water speed is in Region 1=Slow= 0.305 and Flow controller tendency is Towards Closed Mf = 0.463

Table 8 Second observation

Sr. No	Observation	Results
1.	**MATLAB Simulation Value**	**0.463**
2.	Design Value	**0.379**
3.	Difference	**0.084**

IV EMBEDDING THE FUZZY LOGIC SYSTEM IN MICROCONTROLLER USING PSEUDO CODE

Fuzzy logic rules itself cannot be burnt in microcontroller as it is nothing more than software based controller. Fuzzy itself means approximation, Foggy or unclear. So as we make program in Assembly and burn it in microcontroller it cannot be done for fuzzy logic controller. We have to make and Pseudo code to make a fuzzy program work in microcontroller as shown in figure 6.

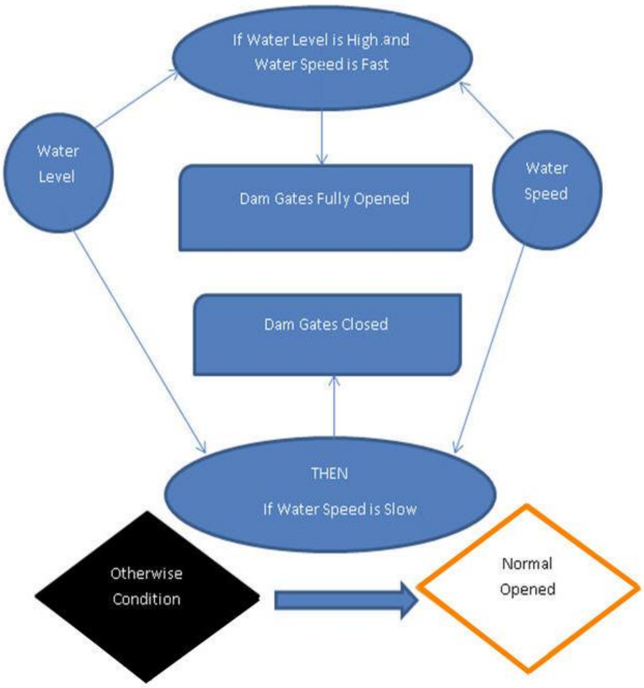

Figure 6 Pseudo code

Here
P0=1st input= Water Level
P1=2nd input= Water Speed
P2=output= Flow Controller
For Water Level:
P0.0=High Level (HL)
P0.1=Low Level (LL)
P0.2= Normal Level (NL)
For Water Speed:
P1.0=Fast (F)
P1.1=Slow (S)
P1.2=Normal (N)
For Flow Controller (Dam Gates):
P2.0=Full Opened (F_O)
P2.1=Closed (C)
P2.2=Normal Opened (N_O)

Of course on the real field sight of dams there are fixed speed and level sensors and big circuitries are present for controlling the opening and closing of dams. In this system we have developed a simple pseudo code based microcontroller circuit which is derived from the results of fuzzy logic based controller. This system gives and over look of how the opening and closing of dam gates work. This system is the best interpretation of the above used fuzzy system that whenever there are extreme conditions the system will show its extreme action (F_O or C) otherwise it will work in normal condition. Any of the microcontrollers can be used PIC or ATMEL. But here atmel **89c51** microcontroller has been used. The three LED's show the different mfs of flow controller (Dam gates) and the logic states show different mfs of two of the inputs. Proteus software has been used to develop the microcontroller circuit.

LED RED= Full Opened Mf
LED BLUE= Closed Mf
LED GREEN= Normal Opened Mf
P0.0=1=Water Level=High Level (HL)
P1.0=1=Water Speed=Fast (F)
P2.0=LED RED Glows= Flow Controller (Dam Gates) = Full Opened (F_O), as shown in figure 7.

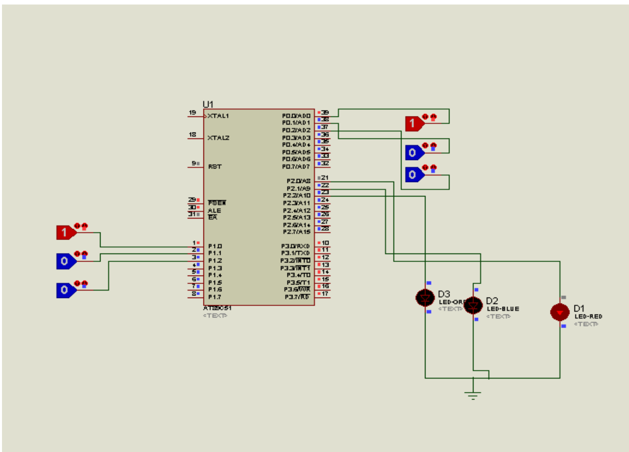

Figure 7 Full opened dam gates

P0.1=1=WaterLevel=Low Level (LL)
P1.1=1=Water Speed=Slow (S)
P2.1=LED BLUE Glows= Flow Controller (Dam Gates) = Closed (C), as shown in figure 8.

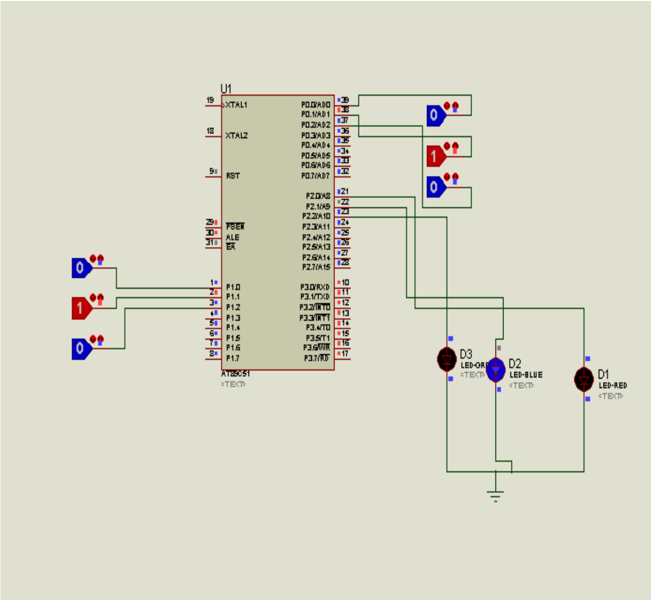

Figure 8 Closed dam gates

There is else condition means between the extreme conditions the no matter what is the condition the system will show results in normal region as shown in figure 9.

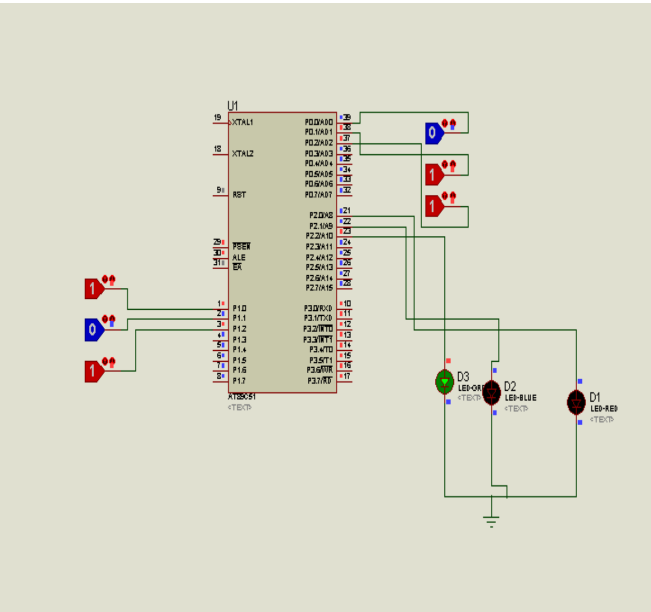

Figure 9 Else condition or normal opened dam gates

V CONCLUSION

It has been seen that whenever the flood season comes lot of water from the dams is wasted and which results into unbearable consequences. The human life loss, Agricultural and Power losses are the major factors of this destructive phenomenon. These losses could be due to land sliding and flood. For the past few centuries many major dam failures has been seen. This resulted into much human causality. It has been noticed that destruction was caused due to the negligence about the speed of water coming into dams from different sources and water level in the dams. As the water level and water speed are two major factors in the flow controller system of dams. It is also noticed that if dam gates are not controlled (opening, closing or half way opening) then it can result in same losses mentioned above. This system provides the an efficient way of controlling dam gates that the gates will be opened or closed in accordance with the water speed and water level. The system was checked for practical results using microcontroller and showed promising results. Of course the practical conditions are always different from the actual conditions but if this system given a chance it will show better results. This system is very novel and strong. The close results of this system show its importance and efficiency. This study can be improved to more precise level and more can be done in this field.

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