APPLICATION OF KNOWLEDGE BASED ENGINNERING TECHIQUES IN WATER RESOURCES DEVELOPMENT

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ABSTRACT

Central Water and Power Research Station (CWPRS) is a premier National Institute working on various physical tidal/wave/ river discharge models. In the recent days, CWPRS has been applying knowledge based engineering tools such as Artificial Neural networks, Fuzzy logic and SCADA techniques in analyzing/ controlling the physical models. This techniques have resulted is highly accurate measurement and control of water resources and hence the resources are better managed. One such model study completed with SCADA control system to regulate and measure River discharges for a proposed national important development project by CIDCO for an international airport developmental study. This system. In order to reproduce the hydrographs, which are nonlinear in type a very accurate and prediction based controller is required and hence a PID+ Fuzzy controller is being developed and configured with the Elipse SCADA software. The software is capable of monitoring unlimited inputs. It will monitor five flow meter inputs and 8 water level sensor inputs. It controls five pneumatic control valves. Presently the system is operated with a PID controller, which cannot reproduce the nonlinearities in the river flow pattern. The full length paper is a development work carried out at CWPRS by project students on LABVIEW SCADA, showing the present graphs and the improvements obtained with Fuzzy logic controllers. This is the first time such model is tried for a river discharge simulation system. This approach allows the users to better utilize the water resources and hence reliable and quality results are obtained. It also improve the efficiance of the model studies by simply modifying the discharge quantities on a computer.

INTRODUCTION

In the control technique very often face complex dynamic systems with non linear or time variable behavior [1]. Therefore, such a process is difficult to determine in a model since it can be inaccurate and therefore often useless [2]. Keeping these problematic processes in mind we go for fuzzy logic. The concept of certain degree or multivalence is the fundamental concept stated by Dr. Lofti which introduced fuzzy logic.

SCADA or Supervisory Control And Data Acquisition is a large scale control system for automated processes like municipal water supplies, power generation, steel manufacturing, gas and oil pipelines etc. SCADA also has applications in large scale experimental facilities, like those used in nuclear fusion. Here we are using SCADA to control river discharges in the model which is an automated control process. These systems typically implement a distributed database, commonly referred to as a tag database, which contains data elements called tags or points. A point represents a single input or output value monitored or controlled by the system in river discharges. Points can be either "hard" or "soft". A hard point is representative of an actual input or output connected to the system where flow meters, valve etc. are connected. While a soft point represents the result of logic and math operations applied to other points in system model. We are using ELIPSE make of SCADA software to simulate the model. Data values are normally stored in SCADA system and further prediction is calculated. Prediction based controller is required to reproduce accurate hydrograph using PID and fuzzy based controller. These knowledge based models are easy to understand, they have tolerant of imprecise data, these logics are flexible, can model nonlinear functions of arbitrary complexity, can be built on top of the experience of experts, can be blended with conventional control techniques and more importantly they are based on natural language. The basis for fuzzy logic is the basis for human communication.

Hence we have developed a microcontroller based non linear simulator to control and process the hydrograph collected from real site in the model and interfacing with various required sensors. The process output is analyzed with FFT/signal processing techniques.

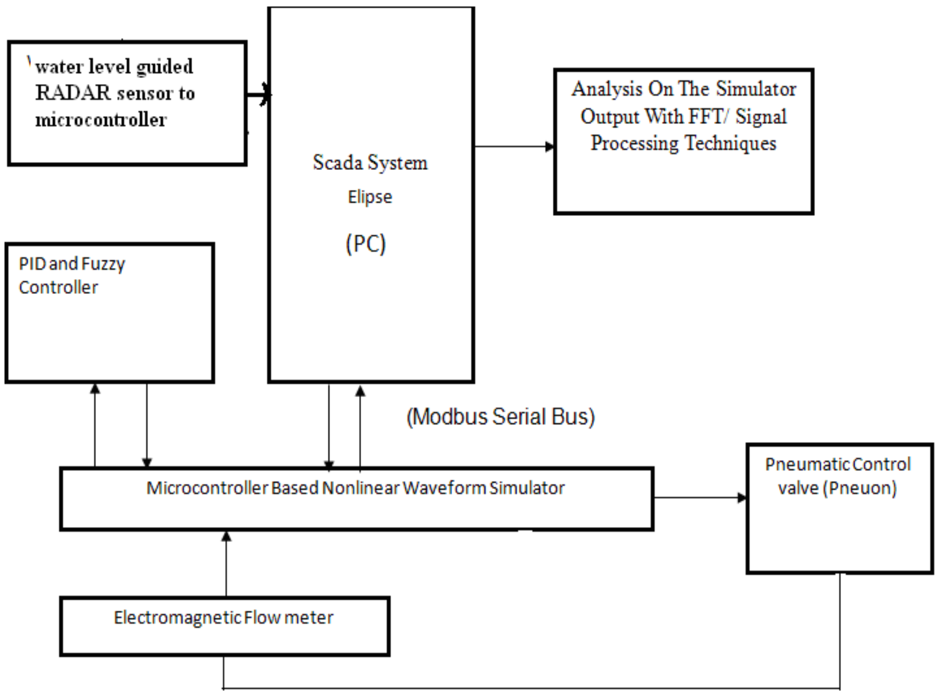


FIG1.1: Block Diagram of the SCADA process for river simulation system

OVERVIEW

This research is carried out at Central Water & Power Research Station (CWPRS). Currently CWPRS is working with the models, without the use of much modern technology. And with the use of advanced technology (SCADA, Fuzzy) we can get the accuracy and efficiency further enhanced by **10%**. For more accuracy we need automation. In this we are trying to reproduce the river discharge using automation control which has never been tried in India.The aim of this study is to build a microcontroller based automated non linear waveform simulator using prediction control like fuzzy logic controller and PID controller. Graphic user interfacing like SCADA is used to analyze the signals flowing throughout the system at every point. Output of the system will be analyzed using signal processing technique like FFT.

Here we are using static data logging system. Data can be hydrographs which are collected from the actual site and acts as input to SCADA. SCADA or Supervisory Control And Data Acquisition is a large scale control system for automated processes. Elipse SCADA software is used which is accessible, friendly, and totally flexible. It is the ideal tool for automation, for it eliminates the need for lengthy, expensive solutions, enabling the process with competitiveness, efficiency, and quality. This microcontroller based system consists of Electromagnetic Flow meters to measure the flow and control valve to regulate it as per the discharge hydrographs collected from the site. This system will monitor 5 flow meter inputs and 8 water level sensor inputs. It controls five pneumatic control valves.

In order to reproduce the hydrographs, which are nonlinear in type a very accurate and prediction based controller is required and hence a PID and fuzzy controller was procured and configured with the Elipse SCADA software. During the testing and calibration of the system it is mandatory to simulate the input signal from a micro controller based random wave generator. This will allow validating and calibrating the sensors.

Microcontroller:

In this we are using ARM microcontroller to control stepper motor for pneumatic valve. Here microcontroller based simulator generates a kind of river discharge and this is fed to SCADA, the errors are calculated from SCADA and given to simulator and according to that the Fuzzy logic controller and PID controller works for further prediction and then Simulator(microcontroller) decides whether to open or close the valve.

PID Controller:

The PID algorithm is programmed into the system to calculate the error signal of the set point water level to acquired point water level. Due to use of PID algorithm, the system has eliminated steady state error (Due to I factor) and reduced the overshoot (Due to D factor), settling time, oscillation and resulted in higher stability.
PID controllers rely on three main elements: the process variable, the set point, and the manipulated variable. The process variable refers to the system's current condition. The set point refers to the system's intended conditions. The manipulated variable refers to the actual mechanism that allows the system to change its conditions.

Fuzzy Controller:

We are using the fuzzy control technique because of the Real-World Vagueness and we know river discharge is never linear. Fuzzy logic is useful when we are not very sure of the process model. Fuzzy logic addresses applications perfectly as it resembles human decision making with an ability to generate precise solutions from uncertain or approximate information. It fills an important gap in engineering design methods left by mathematical and logic-based approaches. But the disadvantage is that Prior knowledge is required. If a case is missed, the controller would not work properly.
Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. The information is allowed to be partial, i.e. a matter of degree; imprecise (approximate); granular (linguistic); perception based. Fuzzy logic seems closer to the way our brains work. As the complexity of a system increases, it becomes more difficult and eventually impossible to make a precise statement about its behavior, eventually arriving at a point of complexity where the fuzzy logic method born in humans is the only way to get at the problem.
The main advantages of the fuzzy logic are the reduction of overshoot and stricter regulation of steam temperature. Fuzzy logic controller has a very good result for non linear dynamic processes **[3].** Using fuzzy logic in industrial applications in recent years has increased. Japanese industry has launched an aggressive marketing of fuzzy ideas in the form of first commercial outputs **[4].**
The fig. 1.2 shows the fuzzy logic controlled analysis method. The input is the real time data like temperature, river discharge etc. During the processing fuzzification is done based on the "IF-THEN" conditions and in the fuzzification process fuzzy variables and membership functions are added. Fuzzification process is followed by defuzzification process. After the defuzzification process we again get the real time data at the output side.

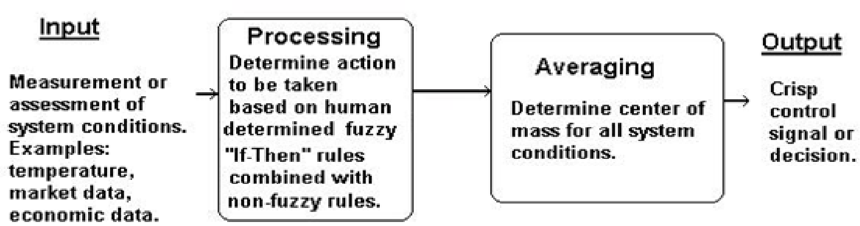


FIG1.2: The Fuzzy Logic Control Analysis Method

Illustration of fuzzy logic with the help of an example:

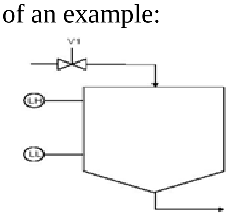


FIG 1.3: Process Diagram of a Feed Tank

The objective is to control the valve V1, such that the tank is refilled when the level is as low as LL, and stop the refilling when the level is as high as LH. The sensor LL is 1 when the level is above the mark, and 0 when the level is below; likewise with the sensor LH. The valve opens when V1 is set to 1, and it closes when V1 is set to 0. In Boolean logic, the controller can be V1= 1, if LL switches from 1 to 0, if LH switches from 0 to 1. In Fuzzy Logic, if the level is low then open V1, If the level is high then close V1.

SCADA System:

SCADA means Supervisory control and data acquisition. SCADA refers to a system that collects data from various sensors at a model, and then sends this data to a central computer which then manages and controls the data. The term SCADA refers to the entire central system. The central system usually monitors data from various sensors like EM flow meters, control valve, water level sensors, that are either in close proximity or off site (sometimes miles away). A SCADA system gathers information, transfers the information back to a central site, carrying out necessary analysis and control and displaying the information in a logical and organized fashion. These systems can be relatively simple, such as one that monitors environmental conditions of a small office building, or very complex, such as a system that monitors all the activity in a nuclear power plant or the activity of a municipal water system **[5].**

SCADA systems typically implement a distributed database, commonly referred to as a tag database, which contains data elements called tags or points. A point represents a single input or output value monitored or controlled by the system in river discharges. Points can be either "hard" or "soft". A hard point is representative of an actual input or output connected to the system where flow meters, valve etc. are connected. While a soft point represents the result of logic and math operations applied to other points in system model. A SCADA application has two elements:
1.The process/system/machinery to monitor a control this can be a power plant, a water system, a network, a system of traffic lights, or anything else.
2. A network of intelligent devices that interfaces with the first system through sensors and control outputs. This network, which is the SCADA system, gives the ability to measure and control specific elements of the first system.

For this we are using Elipse SCADA software. The SCADA basically here acts as a GUI (graphical user interface). This software is available in four modules: View, MMI (Man Machine Interface), Professional and Power. All the four mentioned modules have Configurator, Runtime, and Master versions. Elipse SCADA combines high performance to strong versatility, represented by its several features, which facilitate and speed up the task of developing your application.

Totally configurable by the user, it allows the monitoring of variables in real time through graphs and objects related to the physical variables in the field. It is also possible to make activations and to send or receive information from data acquisition equipment. In Elipse SCADA different tools like ORGANIZER and TAGS are present. The development of an application in Elipse SCADA is based on the Organizer tool. It allows a simple and organized view of the whole application, helping in the edition and configuration of all objects involved in the system through a hierarchical tree. Tag values or associate Attribute value can be displayed by the animation objects in the Screen, used in calculations through the scripts, modified through the operator's actions, and so on. In creating Tags, the user will be able to organizer them in Groups as he may wish, so to make it easier the search and identification during the set up process. Different types of tags present in Elipse SCADA are: PLC, DDE, Demo, Expression, Block, RAM, Matrix, and Counter. With SCADA, you can eliminate the need for site visits by your personnel for inspection, adjustments and data collection. SCADA software enables you to monitor the operations in real time. It can also make modifications to the system, auto-generate reports and trouble-shoot. Thus once the system is installed, it reduces operational costs and improves the efficiency of the set-up. SCADA systems are equipped to make immediate corrections in the operational system, so they can increase the life-period of your equipment and save on the need for costly repairs.

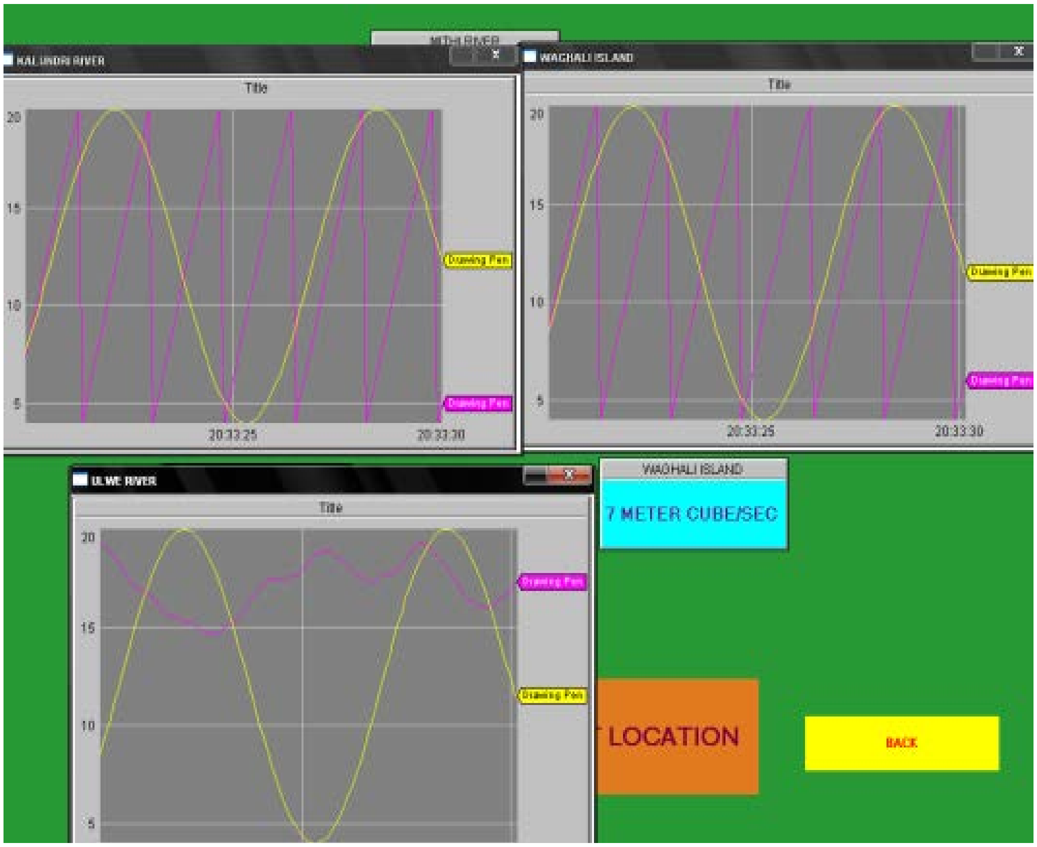


FIG1.4: Snapshot Of Scada Simulation on LABVIEW

Electromagnetic Flow meters:

These flow transmitters accurately measure the flow rate of conductive liquids & slurries in closed pipes. Due to simple & rigid design, the flow transmitter is an obstruction less & maintenance free instrument in place of conventional mechanical flow measuring device. The use of 'Pulsed DC' technology offers highest ability & better measuring accuracy in the form of electrical signal 4 - 20 mA DC linearly proportional to volumetric flow. The instrument is based on Faraday's law of electro-magnetic induction. A magnetic field is generated by the instrument in the flow tube. The fluid flowing through this magnetic field generates a voltage that is proportional to the flow velocity. Corresponding electrical output is provided with respect to measuring voltage.

The EMF consists of a non-ferromagnetic measuring tube with an electrically insulating inner surface, and magnetic coils and electrodes that are arranged diametrically on the tube and are in contact with the process liquid through the tube wall. The field coils through which current flows generate a magnetic field with induction B perpendicular to the longitudinal axis of the tube

Guided wave RADAR sensor:

These sensors have highest accuracy. They can measure water level even at the height of 1mm.This 1mm of height is important because it's of physical model, and in actual model this 1mm would be around thousands of meters, which is important. We use high frequency because at higher frequency accuracy increases, therefore we use RADAR water level sensors. Guided wave radar is unaffected by shifts in pressure, temperature, or product specific gravity, making it reliable for level measurement.

WORKING

The samples of the river discharge i.e. hydrographs which are non-linear in nature are collected from the site. Hydrographs are then given as static data to the SCADA. Microcontroller based simulator generates a kind of river discharge whose output current is between 4-20mA.So output of simulator is fed to SCADA(PC),and SCADA will generate the waveform and the user will get a clear idea about the difference between given data and produced data. The errors are calculated from SCADA (PC) and given to simulator and according to that the Fuzzy logic controller and PID controller works for further prediction. The PID controller which works on the rate of change of error and change of error provides more accuracy and precision to the obtained data from the Fuzzy controller. Simulator decides whether to open the valve or to close as per prediction controllers.

The water level is measured by the Guided Wave Radar sensor. The flow of water is measured using the Electromagnetic flow meter which produces electrical output (current) which ranges from 4-20mA .These output of sensors are fed to microcontroller simulator. Depending upon the input (current) value, simulator will generate the corresponding frequency which in turn will run the stepper motor and hence the valve. In the DC motor the windings are in the rotor so that the heat does not have a direct path to the outside environment, and hence we are using stepper motor where the windings are in the stator **[6].**The simulator output is also given to PC where we can analyze and compare the desired and the actual output obtained in the frequency domain using FFT.
In the fig. illustrated the green line shows the output from the PID controller and the red line shows the actual desired output. Since the Fuzzy controller works on the partial truthness, it's observed that the error present in the above fig. in the form of the difference between the actual and observed output can be removed. Again, we are using the PID controller also all though using Fuzzy controller because fuzzy always tries to reach the actual output but will never reach. The results showed that fuzzy logic controller gives better results than the conventional PID controller **[3]**. So, using the PID control technique (proportionality) we can make the waveform almost correspond to the desired output.

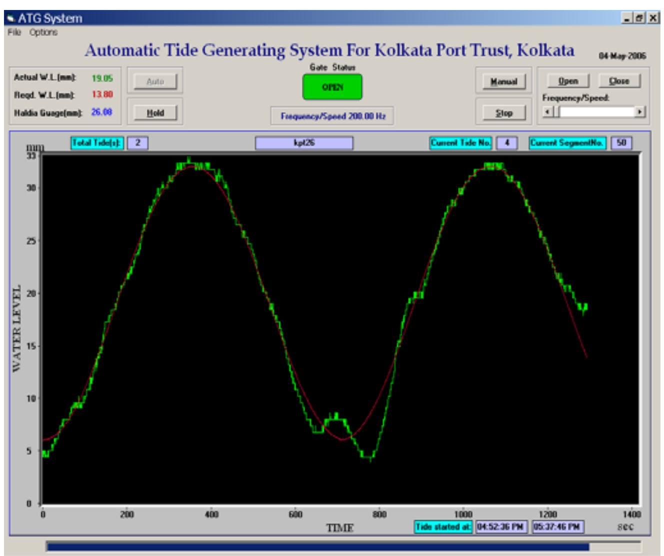


FIG1.5: PID Control Output

HARDWARE REQUIREMENT

In this we are required to use a microcontroller simulator using ARM7 which is capable of generating a 4-20mA. ARM7 kit is interfaced with the computer's serial port to send and receive data. ARM7 microcontroller should be programmed in such a way that it should drive a stepper motor to control the pneumatic valve.

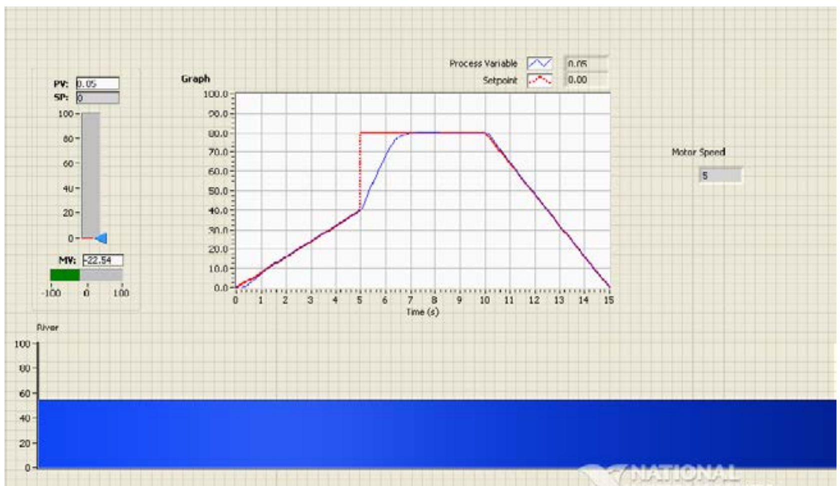
SOFTWARE REQUIREMENT

In this we are using NI LABVIEW software for fuzzy logic programming, SIDE ARM terminal software (by SPJ Systems) is used for the interfacing of the ARM7 with the stepper motor and controlling the pneumatic valve.

Labview:

LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to help you troubleshoot code you write.

Labview simulation:



CONCLUSION:

The result of this analysis shows that fuzzy logic controller is useful in applications of nonlinear static and dynamic characteristics, where classical methods with usually classical PID controller cannot be a satisfactory outcome. Fuzzy controller allows the user apply their knowledge of the problem and transfer it to an appropriate system environment which is close to the human way of thinking.

SCADA systems have been used for years in the utilities industry with great success. Now more than ever, it is important that our critical infrastructures such as power grids, water processing systems, and the Public Switched Network (PSN), be monitored and protected. Today's SCADA systems are able to take advantage of the evolution from main frame based to client/server architectures. These systems use common communications protocols like Ethernet and TCP/IP to transmit data from the field to the central master control unit. SCADA systems, like other computer systems, are subject to many common security attacks such as viruses, denial of service, and hijacking of the system. But, Elipse SCADA the software which we are using in this have a lot of security, even if the system crashes a back up file is stored automatically by the software.

REFERENCES

[1] D.Dzonlagic , Basics of the design of fuzzy control systems, Faculty of Electrical Engineering and Computer Science, Maribor, 1995.
[2] C.C. Lee, Fuzzy logic in control systems: fuzzy logic controller-parts 1 and 2, IEEE Transactions an systems, Man and Cybernetics 20/2 (1990) 404-435.
[3] Journal of Achievements in Materials and Manufacturing Engineering, volume-45 issue-2, April 2011.
[4] M.Sugeno, Industrial applications of fuzzy control, Elsevier Science Pub, 1985.

[5] NATIONAL COMMUNICATIONS SYSTEM, TECHNICAL INFORMATION BULLETIN 04-1, Supervisory Control and Data Acquisition (SCADA) Systems, October 2004.
[6] M.Zribi and J.Chiasson. "Position control of a PM stepper motor by exact linearization". IEEE Trans. Automat. Contr.,36,(5), 620-625(1991).
[7] McClanahan, SCADA and IP: is network convergence really here?, Industry Applications Magazine, IEEE , Volume: 9 , Issue: 2 , March-April 2003 Pages:29 - 36
[8] www.spjembedded.com
[9] www.cwprs.gov.in
[10] www.mowr.gov.in

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Shri. M.Selvabalan graduated in Electronics and Communication Engineering from CEG, Anna University, Chennai in 1993. He has done his Masters from the same college in and completed his course work of six months from Electrical Engineering department of IIT Bombay, Mumbai in 1999. He has joined CWPRS, Pune in 1998 November as a Research Officer and now working as a Senior Research Officer from 2005. He has expertise in developing control systems, implementation of projects related to Reservoir sedimentation studies with GPS, Echosounder, Dam instrumentation, River simulation, tide generation etc. He is actively involved in automating several physical models, which are presently manually operated. He has also served as faculty at Instrumentation division at MIT, Chennai for two years. He is associated technically with various institutes under University of Pune and Kolhapur University. He has more than 20 Papers in conferences and 10 Papers in reputed Journals.