ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 2, Issue 5, May 2015

Online Monitoring of Temperature Control in Nuclear Power Plants with Alarm Indication Using Soft computing Technique

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Abstract: Accuracy, efficiency and effective controlling is a pre requisite of any industry. Developing online monitoring in Automation Control System is a major industrial concern since those systems are more and more complex and involved in many safety critical application fields. The Automation system is being widely used in Power, Steel manufacturing, Oil& Gas, and Petrochemicals for monitoring, advance process control, regulatory, sequential control. This project facilitates bring online monitoring of temperature in nuclear plants along with controlling action using Fuzzy PID controller which overcomes the disadvantages done in the case of manual action.

I. Introduction

Nuclear plant I&C is more complex and varied than the control instrumentation in other industrial applications because of the special nature of nuclear power. A nuclear plant's production must remain continuous and control over the nuclear plant's reactor is impossible, and the potential risks of nuclear energy production require greater redundancy and reliability in plants' control infrastructure (IAEA, 1999).

The control and safety of nuclear power plants depend on temperature and pressure (including differential pressure to measure level and flow).In Pressurized Water Reactor plants, RTDs are the main sensors for primary system temperature measurement. The resistance of the sensing element changes with temperature, and therefore by measuring the resistance, one can indirectly determine the temperature. The number of RTDs in a nuclear power plant depends on the plant design and its thermal hydraulic requirements. For example, PWR plants have up to 60 safety-related RTDs while heavy water reactors such as Candu plants have several hundred RTDs. Pressure transmitters are the next most common I&C component. A pressure transmitter may be viewed as a combination of two systems a mechanical system and an electronic system.

The pressure transmitter's mechanical system contains an elastic sensing element (diaphragm, bellows, Bourdon tube, etc.) that flexes in response to pressure applied. The movement of this sensing element is detected using a displacement sensor and converted into an electrical signal that is proportional to the pressure.

II. Existing System Analysis

The existing method of controlling temperature in a nuclear power plant is shown below with a MPC. In MPC the predicted parameter is main steam and this explained in detail with the behavior of MPC along with the schematic regulation.

2.1 Predictive Controller for temperature measuring system in nuclear power plant

MPC is a controller method which is used in plants or system involving complex dynamics. To make a measure of dynamics is practically difficult so this is to be controlled by analyzing the parameter which a dependent and also measurable. The identified dependent variables which cause or are in some relation changing the independent variable to change are used for prediction (iteration or repetitive calculation). To have a better or clear control over the plant the perdition is done having account of all the following parameters:

i. Current state of the process,
ii. Process variable target and
iii. Limits if any.

Which comprises Programmable Logic Controllers (PLCs) from various manufacturers. Nowadays, Intelligent Electronic Devices (IEDs) are used for precise control and monitoring of power plants as substitutes of hardwired electromechanical devices. Kerman and Kunsman proposed a technique for configuring IEDs. Kumar et al. proposed a fuzzy-based algorithm for preprocessing of the data at RTUs. This ensures that the dependent variables are well maintained within the said limit. Also the prediction keeps

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shifting forward for every stage. Such behavior of the controller is called as receding horizon.

Three factors influence the main steam temperature (MST), namely the steam flow, flue gas heat and de superheating water flow. There are also many different regulation methods adopted according to the different types of regulation mechanism. Among them, the spray de superheating one is the widely used in power plants currently because of its flexibility, simplicity and high controllability.

Due to the super heater's long pipes and complex structure, moreover, hysteretic nature and large inertia, the mode of two stage spray de superheating is used. The first stage de super heater is set at the entrance of the platen super heater, mainly used to protect platen super heater from tube-wall over-temperature, at the same time to adjust MST coarsely.

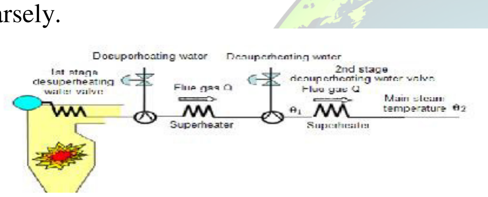

Fig. 2.1 Schematic regulation set up of MST

The second stage de super heater is set at the entrance of final super heater to adjust MST aborately. The typical regulation setup of MST is shown in above Figure 2.2 In this paper, by the simulation platform for 200MW thermal power unit, the controlled object of the MST is simulated. Based on the dynamic characteristics of the MST analysis, two predictive controllers are designed to control two desuperheaters, respectively. The design of predictive control strategy is shown below in Figure. 2.1. For the first stage predictive controller, the controlled variable is the temperature of the second desuperheater inlet, the operating variables is valve opening of the first stage desuperheating water, and the feed forward variables are the main steam flow, main steam pressure and the temperature of the first stage desuperheater inlet.

For the second stage predictive controller, the controlled variable is the main steam temperature, the operating variable is the valve opening of the second desuperheating water, and the feed forward variables are the main steam flow, main steam pressure and the temperature of the second desuperheater inlet steam.

2.2 Proposed Method

The proposed method is mainly developed with an intension to overcome certain disadvantages faces in existing model. Among which delayed response due to manual controlling action is proposed to overcome in this method.

2.2 Lab VIEW Features

Lab VIEW is a platform and development environment for a visual programming language from National Instruments. The graphical language is named "G". Originally released for the Apple Macintosh in 1986, Lab VIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various flavors of UNIX and Linux.

2.2.1 Dataflow Programming

The programming language used in Lab VIEW, also referred to as G, is a dataflow programming language. Execution is determined by the structure of a graphical block diagram (the LV-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, G is inherently capable of parallel execution. Multiprocessing and multi-threading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution.

2.2.2 Graphical programming

Lab VIEW ties the creation of user interfaces (called front panels) into the development cycle. Lab VIEW programs/subroutines are called Virtual Instruments (VIs). Each VI has three components; they are a block diagram, a front panel, and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VIs. Controls and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument. However, the front panel can also serve as a programmatic interface. Thus a virtual instrument can either be run as a program, with the front panel serving as a user interface, or when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the given node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program.

2.3 PID Controller

PID controller is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. The PID controller algorithm involves three separate constant parameters, and is

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accordingly sometimes called three-term control. They are the proportional, the integral and derivative values, denoted P, I, and D. Simply put and these values can be interpreted in terms of time. P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change .The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element. In the absence of knowledge of the underlying process, a PID controller has historically been considered to be the best controller. By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point, and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability. Some applications may require using only one or two actions to provide the appropriate system control. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative Action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system from reaching its target value due to the control action.

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{d}{dx} e(t) \qquad (2.1)$$

2.6 Fuzzy as a temperature controller

The term fuzzy refers as fuzzy logic. They play a main role in soft computing. They are mainly used in plants or system with parameters which are oscillatory and can fall in multiple criterions. This has the advantage that the solution to the problem is that the human operators can understand, so that their experience can be used in the design of the controller.

2.5 Fuzzy based PID controller

It is difficult to set proper P, I and D constants even with conventional PID; if additional constants like a, b and y are used, this control method is no longer practical. To overcome such a problem need for fuzzy arises. In a fuzzy system computers and controllers manipulates the exact values that have been reduced to at most zeros and ones or statements that are either true or false, they do not have the reasoning capability of the human mind.

Controllers with fuzzy logic emulate human beings by assisting the instrument to determine responses between two values. Thus technology allows the temperature controller to function like an expert operator. This parallel updates the knowledge base too. This also keeps a note of the change in limit, history of data and records.

a. Fuzzy sets

The input variables in a fuzzy control system are sets of membership functions this is known as fuzzy sets. The process of converting a crisp input value to a fuzzy value is called fuzzification.

A control system may also have various types of switch, or ON-OFF, inputs along with its analog inputs. In case of discreet or switching devices their controlling options are simple with true value. But in a case like ours where the temperature may change and is found oscillatory due to various parameters needs the assistance of rule base.

b. Rule base

These are formed with simple human understand able codes which is shown below. They possess value like if, then, cold, hot, upper limit and so on. The below illustration is fuzzy representation of a temperature control. In this project we are keenly focused on measuring the temperature and display over temperature once it is found exceeding the high limit. To constitute this the following rules would be needed.

Rule-1:
If Temperature is low limit or below low limit
Then Temperature Low
Rule -2:
If temperature is greater low limit or below high limit
Then temperature Intermediate
Rule -3:
If temperature is greater high limit
Then over temperature

III. RESULTS AND DISCUSSIONS

The result analysis of temperature measuring system is done with consideration of idle state and also when temperature is sensed.

3.1 No temperature condition

The front panel designed and illustrated below is an outcome of the temperature measuring system under the following cases no input temperature sensed. And the system is Idle. This makes the display against temperature (current process temperature) to read zero. Fig. 3.1 Front panel of OLM system without any input

3.2 Output response of temperature

Once the system starts to receive temperature input and execution takes place. The following occurrences are

expected in the temperature measuring system of the nuclear power plant.
i. The instance temperature is at or below the lower limit.
ii. The process temperature of the particular instance is between the high the low limit.
iii. The process temperature is above or at high limit. In both first and second case the display against temperature reads its value. Where the last case the over temperature also used to alarm indication.

One reason is that the implementation of OLM techniques depends on the availability of data from a large network of sensors deployed on equipment such as motors, fans, pumps, etc. While many nuclear power plants have an OLM or predictive maintenance program for equipment outside of their containments, none have OLM programs for equipment inside the containments due to the sensor wiring costs and penetration space limitations (AMS, 2010b).

IV. Conclusion

OLM technologies and techniques have evolved to the point where in many cases equipment failures and/or maintenance needs can be adequately predicted days, weeks, or even months in advance of a system or equipment failure. In general, a Fuzzy logic system provides the lowest overall cost for large-scale OLM applications. In the years ahead, future I&C will be fully digital (software based), distributed, bus connected, amenable to OLM, and qualified to industrial standards.

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