iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** IV **Month of publication:** April 2020

DOI: http://doi.org/10.22214/ijraset.2020.4170

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue IV Apr 2020- Available at www.ijraset.com

An Intelligent Technique for Prevention of Hydrogen Explosion in Nuclear Power Plants

Mohammad Sibgat Ullah[1], Asif Hamid Bhat[2], Shabana Mehfuz[3]
[1, 2, 3]*Jamia Millia Islamia University*

Abstract: ***Nuclear Power Plants are responsible for producing around 11% of the world's electricity and thus, are an essential part of electricity generation worldwide. Despite such importance, large number of severe accidents have been recorded in such reactors in past highlighting our inability to attain precise control over the processes involved in nuclear power harnessing. When the hydrogen concentration in the reactor vessel of the nuclear power plant increases above 4% in atmospheric pressure, it might set course for a hydrogen explosion in such reactors. Hence, it is highly essential to maintain the hydrogen concentration below the 4% limit inside the nuclear reactors. This paper, presents an intelligent approach for prediction, control and maintenance of hydrogen concentration inside the nuclear power generating stations by employing fuzzy inference systems (FIS) trained through ANFIS for such purpose. The developed fuzzy inference system was framed into a Fuzzy Logic Controller which is able to control and maintain the hydrogen concentration in nuclear reactors under severe accident scenarios.***

Index Terms: Nuclear Holocaust, Hydrogen explosion, Fuzzy Inference System, Loss of Coolant Accident, Fuzzy Logic Controller

I. INTRODUCTION

Although, nuclear power plants are the most imminent sources of clean and safe electricity but still we are unable to secure such power generating sources against severe accidents which result in nuclear holocausts. This weakness has been time and again brought forth by several accidental incidents that have occurred in the past in such generating stations. The occurrence of some unfortunate incidents such as Three Mile Island Accident (1979), Chernobyl accident (1986) and Fukushima (2011) have developed fear among the public towards the nuclear power generating stations. Besides, these accidents not only, have affected the minds of common public but also, have to the development of a sense of insatiability among the investors. Hence, ensuring the safety of nuclear power plants has been an important prospective worldwide [1]. In nuclear power plants, chained nuclear fission reactions are carried out in a controlled manner to order to generate heat and then this heat energy is used to produce steam which is finally employed to rotate the turbine of the alternator and thus, generating electricity. The control over the chained fission reactions is achieved with the help of control rod made up of neutron absorbing material. The radioactive fuel for the nuclear reactor is present in the fuel rods in the form of small pellets. In such reactors, water or graphite is used as a moderator which slows down the neutrons which are used to trigger the chain reaction [2] [3]. Besides, one of the most important parts of the nuclear reactors is the cooling system associated with such reactors. In general, water is used as a coolant. This cooling system is responsible for the heat transfer from the reactor vessel to the steam generator section of the nuclear power plant [3]. So, if this system fails, the heat energy generated in the reactor vessel of the nuclear power plant keeps on increasing, finally, leading to severe accidents in such power plants. The failure of the cooling system may occur because of the Loss of Coolant Accident (LOCA). The loss of coolant in such an incident provides a route for the temperature inside the reactor to rise beyond bearable limits resulting in generation of hydrogen gas inside the reaction vessel. When the concentration of hydrogen gas inside the reactor crosses the 4% bearable limit, it triggers hydrogen explosions in such reactors causing a vast destruction. So, the Loss of Coolant has come forth as one of the major issue to tackle in order to improve the safety and security of the nuclear power generating stations. The reason behind the occurrence of LOCA is a break or fracture in any part of the cooling system carrying the coolant to the reactor. The main parts of the primary cooling system for the reactor include: (i) Hot Leg, (ii) Cold Leg and (iii) Steam Generator Tube. A break in any of the aforementioned parts of the cooling system results in LOCA. Although, numerous new techniques and approaches have been utilized to tackle such problems but still we are unable to achieve the desired results [4].

©IJRASET: All Rights are Reserved

This paper suggests the development of a system which is capable of predicting, controlling and maintaining proper concentration of hydrogen gas in the nuclear reactors and hence reducing the risk of hydrogen explosions in such highly expensive enterprise. The development of such a system involves establishment of a Sugeno type fuzzy inference system trained in ANFIS which is able to predict hydrogen concentration inside the nuclear reactors with precision. Such fuzzy inference systems are then utilized as fuzzy logic controllers in order to achieve control over the concentration of hydrogen gas inside the nuclear reactors.

II. HYDROGEN GENERATION IN NUCLEAR POWER PLANTS

Due to the imminent dangers of the unexpected rise in the concentration of hydrogen gas inside the reactor of the nuclear power plants, it has been very important to study the hydrogen generation mechanisms in the nuclear power plants. These hydrogen generating mechanisms are the main reason behind the hydrogen explosion accidents occurring in the nuclear power plants due to the loss of cooling system. The main reagent behind the generation of hydrogen gas in the nuclear reactor is the high temperature developed inside the reactor vessel during severe accident conditions. This high temperature triggers various reactions inside the reactor which lead to the generation of enormous amount of hydrogen gas inside the reactor [1]. The major processes producing hydrogen gas inside the reaction chamber of the nuclear reactors are:

A. In vessel Metallic Oxidation

The generation of hydrogen gas in nuclear power plants under severe accident scenarios is supported by the reaction of the Zircolay (an alloy of zirconium, tin and other metals used as a cladding in nuclear reactors) with steam at high temperatures which leads to the oxidation of the metal alloy and the subsequent production of hydrogen gas. In addition to this, the oxidation process of B_4C absorber material with steam or water at high temperature can also lead to the production of hydrogen gas in the nuclear power plants. This process mainly takes place during the early core heat up. This process not only produces hydrogen gas but also generates more heat which leads to further temperature rise [5].

B. Ex-vessel Metallic Oxidation Due to DCH

Ex- vessel metallic oxidation occurs due to the process known as direct containment heating (DCH). In this process the corium in the nuclear power plants undergoes a fast oxidation causing the release of hydrogen gas in the nuclear chamber. In fact, the Zirconium present in the corium at the time of vessel breach gets oxidized during the process of direct containment heating. This type of vessel breach process is mainly triggered due to a loss of coolant accident. This type of process occurs for a very short time but releases hydrogen gas at a very fast rate and hence, it becomes necessary to study such a process in order to ensure complete safety of the nuclear power plants from the hydrogen explosion [5][1].

C. Ex-vessel Metallic Oxidation Due to MCCI

This type of ex- vessel metallic oxidation is another significant process which leads to the release of hydrogen in the reaction chambers of the nuclear power generating station. This type of oxidation is the result of Metal Core Concrete Interaction (MCCI). In this case, there occurs a reactor vessel bottom breach due to the failure of the cooling system in maintaining proper temperature in the reactor core unit and hence, the corium drop occurs and metal core concrete interaction starts. The Zirconium and Chromium masses present in the corium undergo a fast oxidation with the steam (or hot water) in a CO_2 environment and result in the release of hydrogen gas at a very rapid pace. The CO_2 comes into existence due to the thermal decomposition of the concrete basement. In some nuclear power plants, instead of the release of CO_2 from thermal decomposition process, there occurs a release of CO gas which adds to the instability inside the reaction chamber [5].

Besides, there may take place various other procedures in the reaction chamber of the nuclear reactor which may lead to a less significant production of hydrogen gas. These activities include radiolysis of water and various other corrosion reactions. However, the aforementioned activities are the main reason behind the severe accidents taking place in the nuclear power generating stations.

III. FUZZY INFERENCE SYSTEM

Fuzzy inference system is one of the most important units of fuzzy system developed using fuzzy “If Then” rules which possesses the ability of making decisions. Such systems are able to take in the inputs and process them in accordance to the defined “If Then” rules and produce corresponding outputs. The primary constituents of a fuzzy inference system are:

©IJRASET: All Rights are Reserved

A. Rule Base

The rule base is composed of several "If Then" rules required to define any phenomena for which the fuzzy inference system is being developed. It is considered as the backbone of the fuzzy inference system as such a system always processes inputs following these rules in order to generate outputs [1][6]. All the fuzzy "If Then" rules which are used to develop fuzzy inference systems are mainly composed of three main parts which are as: (i) Antecedent, (ii) Consequent and (iii) Connector. Some simple fuzzy "If then" rules used to make fuzzy inference systems can be given as:

1) IF x is A, then y is B.

2) IF x_1 is A_1 and x_2 is A_2, then y is B.

3) IF x_1 is A_1 or x_2 is A_2, then y is B.

The first part of the rule following if - ("x is A") is known as antecedent. It defines the membership function to which an input variable belongs. The later part of the rule following then - ("y is B) is known as consequent. It defines the membership function to which the output variable belongs. The words "If " and " Then " relate the input membership function to the output membership function. The words "and"/ "or" are connectors which are used only when more than one input variables are employed to develop a fuzzy inference system [7].

B. Database

It is the part of the fuzzy inference system which describes the membership functions which are associated with such a system. These membership functions are used to map the inputs to different sections and then process all the inputs belonging to a peculiar section together while following the "If Then" rules. Different types of membership functions can be utilized to develop the fuzzy inference system. The most popular membership functions employed are the gaussian membership function and the triangular membership function. The gaussian membership function is a bell shaped gaussian curve which defines different regions over the range of the input variable, which is provided as input to the developed fuzzy inference system [1] [4][6].

C. Decision Making Unit

It is the unit which performs operations on the input variables in accordance to the defined fuzzy rules and calculates the output corresponding to the input. This unit of the fuzzy inference system is analogous to the central processing unit (C.P.U) of a computer.

D. Fuzzification Interface Unit

It is the part of the fuzzy inference system which is responsible for converting crisp inputs into fuzzified inputs. This system is only utilized when the input variable to the fuzzy inference system is not fuzzy by nature. As the fuzzy inference system cannot work with the crisp inputs, therefore such inputs need to be fuzzified before being actually fed to the fuzzy inference system. As most of the input variables are crisp by nature, so such a unit becomes an essential part of the fuzzy inference system [6].

E. Defuzzification Unit

The defuzzification unit is used to convert fuzzy output produced by the fuzzy inference system into crisp output. Since, only fuzzy systems have the ability to deal with fuzzy variables and no other system understands such variables. Therefore, the output of the fuzzy inference system should always be crisp by nature so that it can be utilized further. The defuzzification units in fuzzy inference systems are used to tackle such problems. These units can use various methods to defuzzify the output of the fuzzy inference system such as centroid method and weighted average method [8].

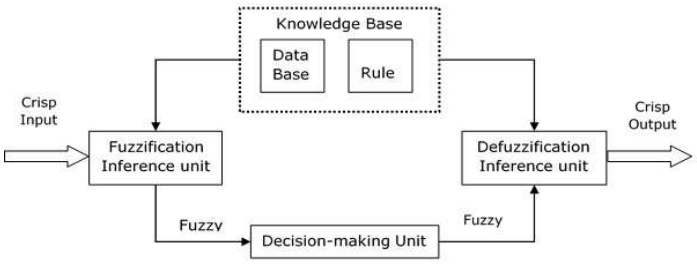


Fig . 1. Functional Block Diagram of Fuzzy Inference System

©IJRASET: All Rights are Reserved

IV. CLASSIFICATION OF FUZZY INFERENCE SYSTEMS

The fuzzy inference systems are mainly classified into two types mentioned as follows:

A. Mamdani type Fuzzy Inference System

Such type of fuzzy inference systems were brought forth by Ebhasim Mamdani in 1975. This type of system was developed in order to achieve anticipatory control over the combined process of a steam engine and a boiler. The rules for developing such a system were framed using the knowledge of the workers working on such steam engines. Development of the Mamdani type fuzzy inference system was the first initiative towards describing a natural situation with the help of "If then" rules which were framed in accordance to the knowledge possessed by the human operators working in such situation [8]. The most important characteristic of the mamdani type fuzzy inference system is that both the antecedent and the consequent part of the "If Then" rules used to develop such kind of system are articulated linguistic constraints. Hence, the rules of the mamdani type fuzzy inference system are simple and straightforward and can be easily related to the practical phenomena for which the mamdani system has been developed. Mamdani type fuzzy inference systems have been highly utilized in the areas of artificial intelligence such as pattern recognition, computer vision and image processing [8].

B. Takagi Sugeno type Fuzzy Inference System

Such type of fuzzy inference systems were developed by Takagi, Sugeno and Kang in 1985. This type of fuzzy inference system is highly utilized in industrial control applications. In many aspects, this type of fuzzy inference system is quite similar to the mamdani type fuzzy inference system. However, there are several attributes associated with this type of system which mark the demarkcation between the earlier developed mamdani and the later developed takagi type fuzzy inference system. This type of system has the input side similar to the mamdani type fuzzy inference system however, its output side is quite different from mamdani system. This is because in mamdani systems, the output membership function can be of various different types however, in takagi systems, the usage of output membership functions is limited to constant or linear. Due to this difference the takagi type fuzzy inference system is able to directly generate the crisp outputs while, on the other hand, the mamdani systems necessarily require a defuzzifier in the output stage in order to defuzzify the fuzzy outputs generated by these systems. Hence, mamdani systems are much more time consuming and tedious compared to takagi type fuzzy inference systems [9].

V. DATA PREPARATION

Although, developing a fuzzy inference system followed by a fuzzy logic controller proves to be an important task in various adaptive control applications. However, such kind of systems cannot be build unless we possess the data information in order to train such type of systems. Hence, data collection and its preparation for utilization in the process of developing a fuzzy inference system is a very important exercise to be carried out in order to achieve our objectives. As we deal with nuclear power plants under severe accident scenarios, so the data information regarding the same can be collected from such catastrophes. However, as the situation we are dealing with is disastrous in nature, hence, the data information cannot be collected directly from such sites which are under the threat of a nuclear holocaust because none of the metering or measurement devices work properly under such situation. Therefore we need to find an alternative way to tackle this situation. So, the data required in order to develop the fuzzy inference inference system is obtained by simulating the nuclear power plant accident scenario with the help of MAAP 4 code (Modular Accident Analysis Program) [1][4].

The Modular Accident Analysis Program is a program created by utilizing several different computer models in order to examine the situation of severe accidents in the nuclear power generating stations. Utilizing such program for simulating the Loss of Coolant Accident scenarios in the nuclear power plants provides us with data information required to built the mentioned fuzzy inference system which is able to control and monitor the hydrogen concentration in nuclear power plants under severe accident scenarios [10]. From this modular accident analysis program we mainly obtain two types of data which are: (i) LOCA break size and (ii) SCRAM time. LOCA break size is the data regarding area of the fracture in any of the components of the primary heat transfer circuit while SCRAM time is the time which has elapsed after emergency shutdown of the reactor [11] [12]. Using the Modular Accident Analysis Program (MAAP 4) code for simulating the situation of severe accident scenario in the nuclear power plant, we are able to collect data regarding three primary loss of coolant accident break positions, which are three different locations on the primary heat transfer circuit of the nuclear power plant and are given as: (i) Hot Leg, (ii) Cold Leg and (iii) Steam

©IJRASET: All Rights are Reserved

Generator Tube [13] [14]. The data regarding the target concentration of hydrogen gas inside the nuclear reactor under severe accident scenarios can be approximated from the graph between the scram time and the hydrogen concentration in the reactor under severe accident scenarios established by the past research in this field [1].

In order to carry out the training of the fuzzy inference system in ANFIS toolbox, the data including 34 LOCA break sizes and the corresponding scram time and hydrogen concentration for each of the break locations is obtained from [13][14][15][1]. Among these 34 data points for each of the break locations, some data points were separately chosen from each group and were utilized as checking data for their particular group. The trained fuzzy inference system with the help of 34 data points was verified against the checking data.

VI. IMPLEMENTATION

In this study, the Takagi Sugeno type fuzzy inference system was developed to predict the hydrogen concentration in nuclear power generating stations under severe accident scenarios. This type of fuzzy inference system was developed by using the fuzzy logic toolbox of the Matlab where in the Loss of coolant accident break size and Scram time were considered as inputs for the inference system and the predicted hydrogen concentration was given as output by such a system. Five gaussian membership functions were defined over the range of the inputs and five linear membership functions were defined over the output range of such system. Then five “If Then” rules were defined as depicted and Fig. 2 which formed the backbone of this inference system. This fuzzy inference system was then exported to the ANFIS toolbox in order to proceed with the neuronal training of this system. The neuronal training of the system was carried out by utilizing the available data. As the data is available for three different LOCA break positions, so neuronal training of the developed fuzzy inference system was carried out separately for all the three break positions resulting in development of three different fuzzy inference systems for each of the three break locations (Hot leg, Cold Leg and Steam generator Tube).

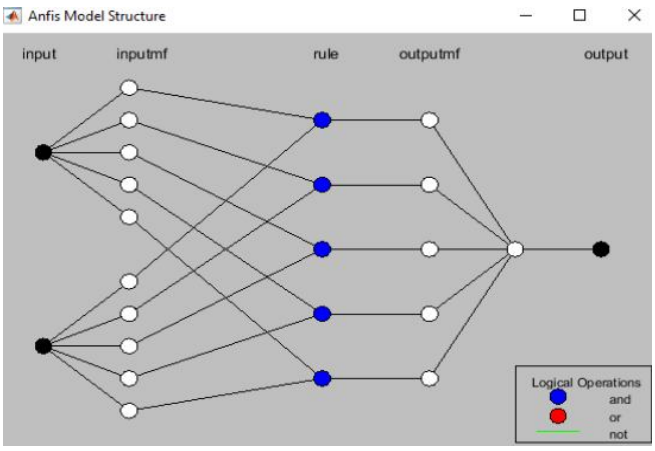


Fig. 2. ANFIS view of the fuzzy inference system with five rules

The training of the developed Takagi Sugeno type fuzzy inference system, itself changed the membership functions of the developed input/output rules and their weights in such a manner to reduce the error between the targeted output and the predicted output. Fig. 3 depicts the ANFIS training of the fuzzy inference system carried out for Hot Leg LOCA break position. In the similar manner, training sessions were carried for Cold Leg and SGTR break positions as well which utilized the training as well as checking data available for all the three LOCA break positions.

In the similar manner, simulations were carried out for FIS developed with 3 and 7 fuzzy rules for each break position, however, the results came out to be most desirable while utilizing 5 fuzzy rules. The reason behind this is the less availability of data, as only 34 data points for each break position available in [15] [16] were utilized. Also, training error of around 0.119%,0.112% and 0.05% where obtained for hot leg, cold leg and SGTR break positions. This training error is very less compared to the RMS error obtained in [1]. The main reason behind obtaining such low error percentages is the utilization of very less data (only 34 available data points[15] [16]) compared to the 200 data points utilized in [1].

©IJRASET: All Rights are Reserved

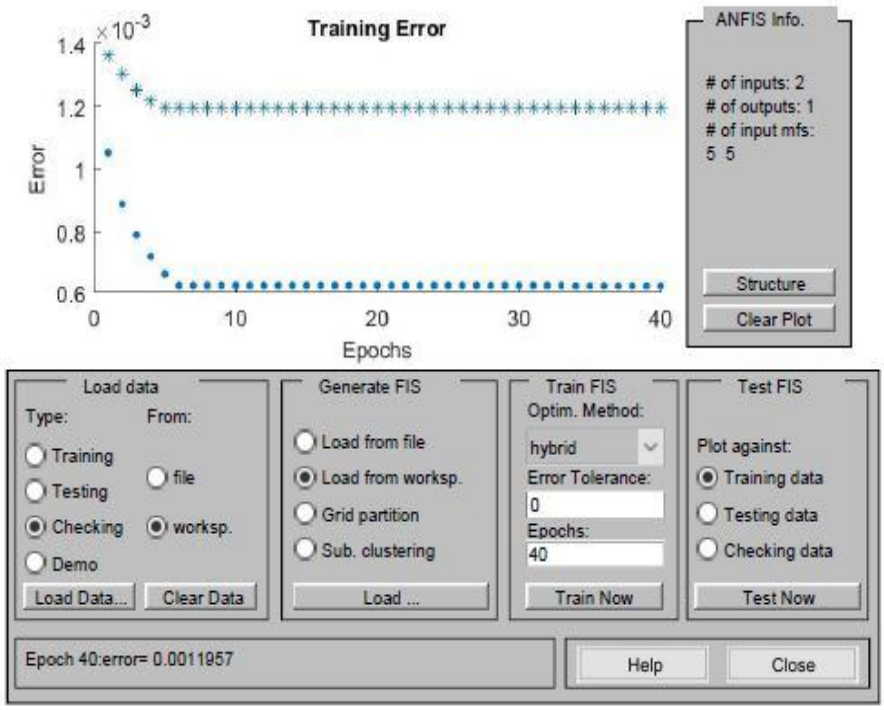


Fig.. 3. Training of the developed F.I.S for Hot Leg LOCA break position

In order to verify the developed fuzzy inference systems, a proper simulation environment was set up in the Simulink separately for each LOCA break position. Fig.4 depicts the simulation environment set up for Hot Leg LOCA. In the similar manner, simulation environment was set up for other break positions and a fuzzy logic controller based on the developed FIS was used. The X-Y plot of the Target Hydrogen Concentration vs Predicted Hydrogen Concentration was obtained for each of the developed FIS as depicted in Fig.5 and it brought forth an almost linear curve in each case, thus, verifying the developed FIS.

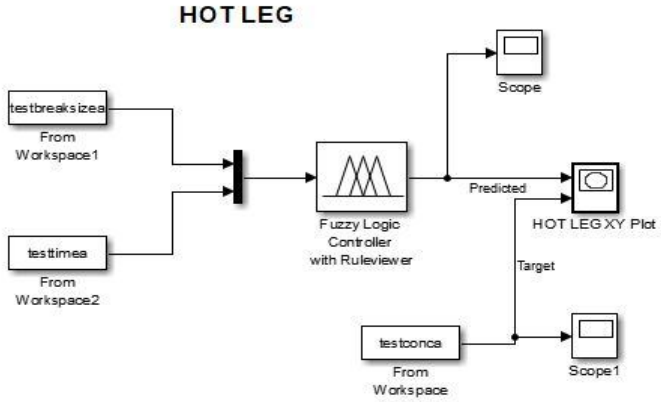
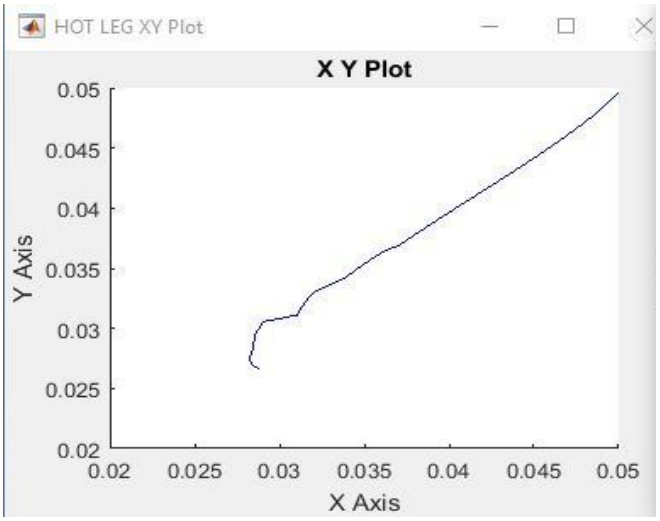


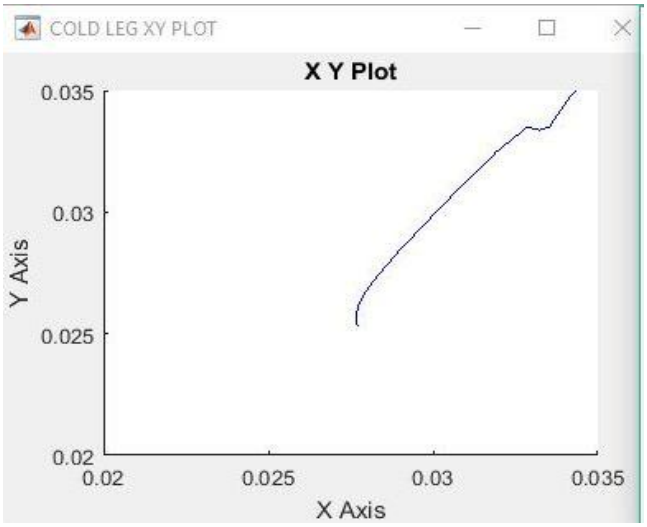
Fig. 4 Simulink Set up for testing the developed FIS for Hot Leg LOCA

In order to achieve automatic control over proper maintenance of hydrogen concentration in the reactor vessel of the nuclear power plant, we need to develop another fuzzy inference system which could utilize the data of the predicted hydrogen concentration given out by the earlier developed FIS and in accordance to the predicted hydrogen concentration, set up a valve into motion. The motion of the valve would enable the venting of the hydrogen gas from the reactor vessel of the nuclear reactor.

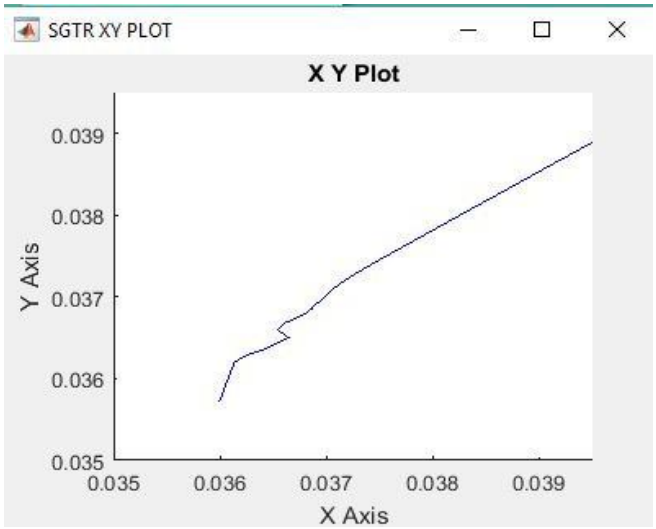
©IJRASET: All Rights are Reserved



(a)



(b)



(c)

Fig. 5. XY Plots of FIS developed for: (a) Hot Leg, (b) Cold Leg, (c) SGTR LOCA break positions

©IJRASET: All Rights are Reserved

Simulation of control system to be utilized for maintaining proper concentration of hydrogen gas inside the nuclear reactor was developed separately in simulink for each of the three LOCA break positions. Fig. 6 presents the model developed for Hot Leg LOCA. In the similar manner, the simulation models were developed for other LOCA break positions and the motion of the valve and the predicted hydrogen concentration for some periodic inputs (sinusoidal and square wave inputs) was analyzed. This analysis depicted that as soon the predicted hydrogen concentration increases, the valve open up and as the predicted hydrogen concentration decreases, the valve closes as presented in Fig. 8. Hence, the proper working of the adaptive control system separately developed for each of the LOCA break positions is verified by these results.

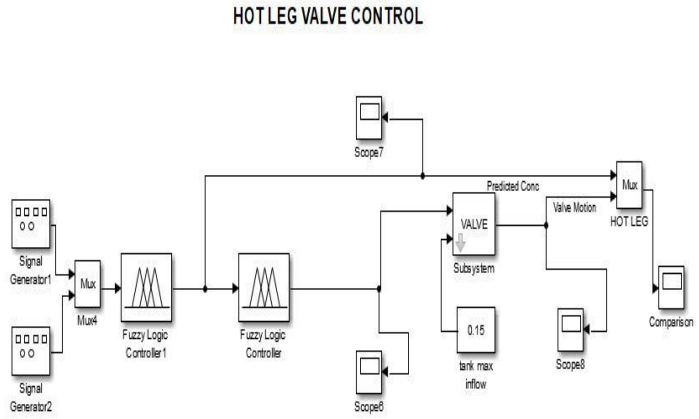


Fig. 6. Control system simulations developed for Hot Leg LOCA

In addition to this, when we ought to deal with a nuclear power plant accidents in real time, any one of the three or any combination of the three types of break accidents may occur and we may not be able to categorize as which type of LOCA incident has occured. Therefore, we need to develop an control system which is able to deal with all the three types break accidents simultaneously. Hence, the simulation of such type of control system was set up in simulink as shown in Fig. 7 and its working was verified by analysing the combined predicted hydrogen concentration and combined valve motion signals. This analysis depticted that as soon as the combined predicted hydrogen concentration increases, the combined valve open up and as the combined perdicted hydrogen concentration decreases, the valve closes as presented in Fig. 8 Hence, the proper working of the combined control system was verified.

In the results presented in the Fig. 8, the plot (a) depicts the working of the combined valve control system, the plot (b) is associated to Hot leg valve control system, the plot (c) verifies the working of the Cold Leg valve control system and the plot (d) is related to SGTR valve control system..

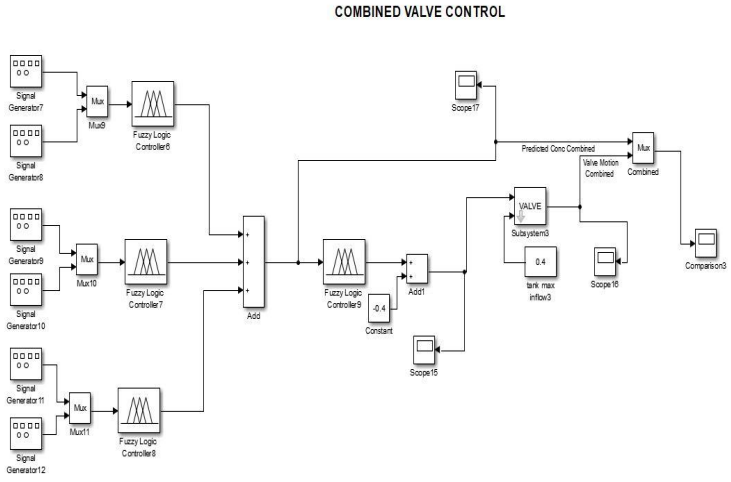


Fig. 7 Combined Control System simulation in simulink

©IJRASET: All Rights are Reserved

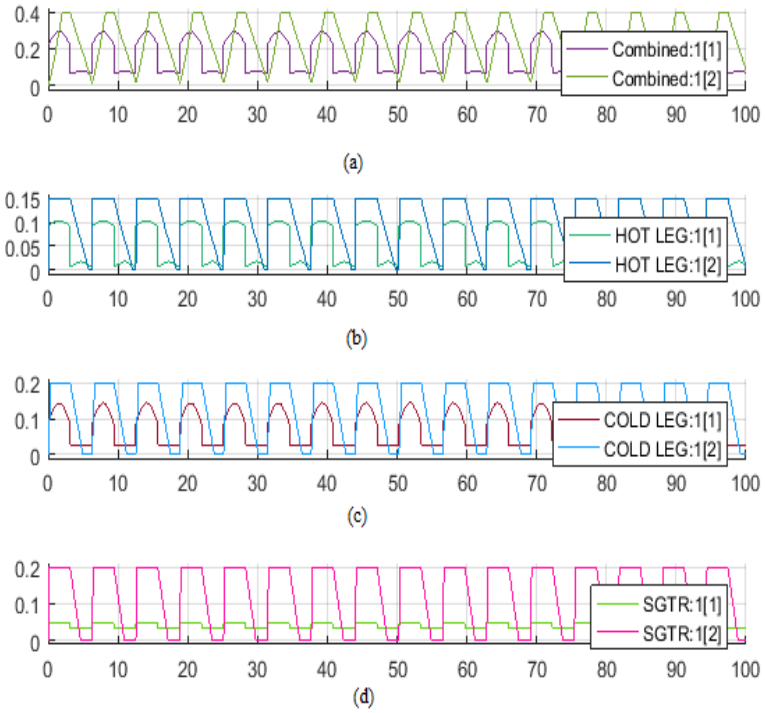


Fig. 8 Results verifying the working of each of the developed control systems for (a) Combined valve control, (b) Hot Leg valve control, (c) Cold Leg valve control and (d) SGTR valve control.

In each of the plots in Fig. 8, signal 1 represents the predicted hydrogen concentration and the signal 2 represents the corresponding valve motion and it is noticed that for every valve control system developed (Combined,Hot Leg, Cold Leg and SGTR), the valve motion shows an upward trend as soon as the predicted hydrogen concentration increases and a downward trend as soon as the predicted hydrogen concentration decreases.

VII. CONCLUSION

In order to prevent the nuclear power generating stations from being destroyed by severe accidents in future it is necessary to control and maintain the hydrogen concentration inside the reactor vessels of such reactors within the permissible limits. Usually, when the hydrogen concentration in these reaction chambers exceeds the 4% limit, a hydrogen explosion is likely to occur in such a situation giving rise to a nuclear holocaust. The main reason for the generation of hydrogen gas in the nuclear reactors is the high temperature present inside the reactors which is developed because of the failure to the cooling system which is responsible for the transfer of heat energy from the reactor vessel to the heat exchanger. This failure of the cooling system may occur because of the fracture in any of the components of the primary heat transfer circuit which is the part of the cooling system.

In this study, a unique hybrid approach of utilizing the fuzzy logic toolbox of Matlab to develop a fuzzy inference system is brought forth. This inference system is trained using the ANFIS toolbox present in Matlab and then employed to build a fuzzy logic controller that can predict, control and maintain the hydrogen concentration in the nuclear power plants under severe accident scenarios. In future, it is required to develop the reactor vessel of the nuclear reactor with such an architecture which prevents the escape of heat energy from the nuclear reactor during venting process and hence, improving the efficiency of such power generating stations [17][18][19]. Also, a mechanism can be developed which would make it possible to utilize the excess hydrogen gas removed from the nuclear reactor and hence, increasing the profits obtained from such power plants [20] [21].

VIII. ACKNOWLEDGMENT

The authors express sincere gratitude to Department of Electrical Engineering, Jamia Millia Islamia, New Delhi for its support throughout the research.

©IJRASET: All Rights are Reserved

REFERENCES

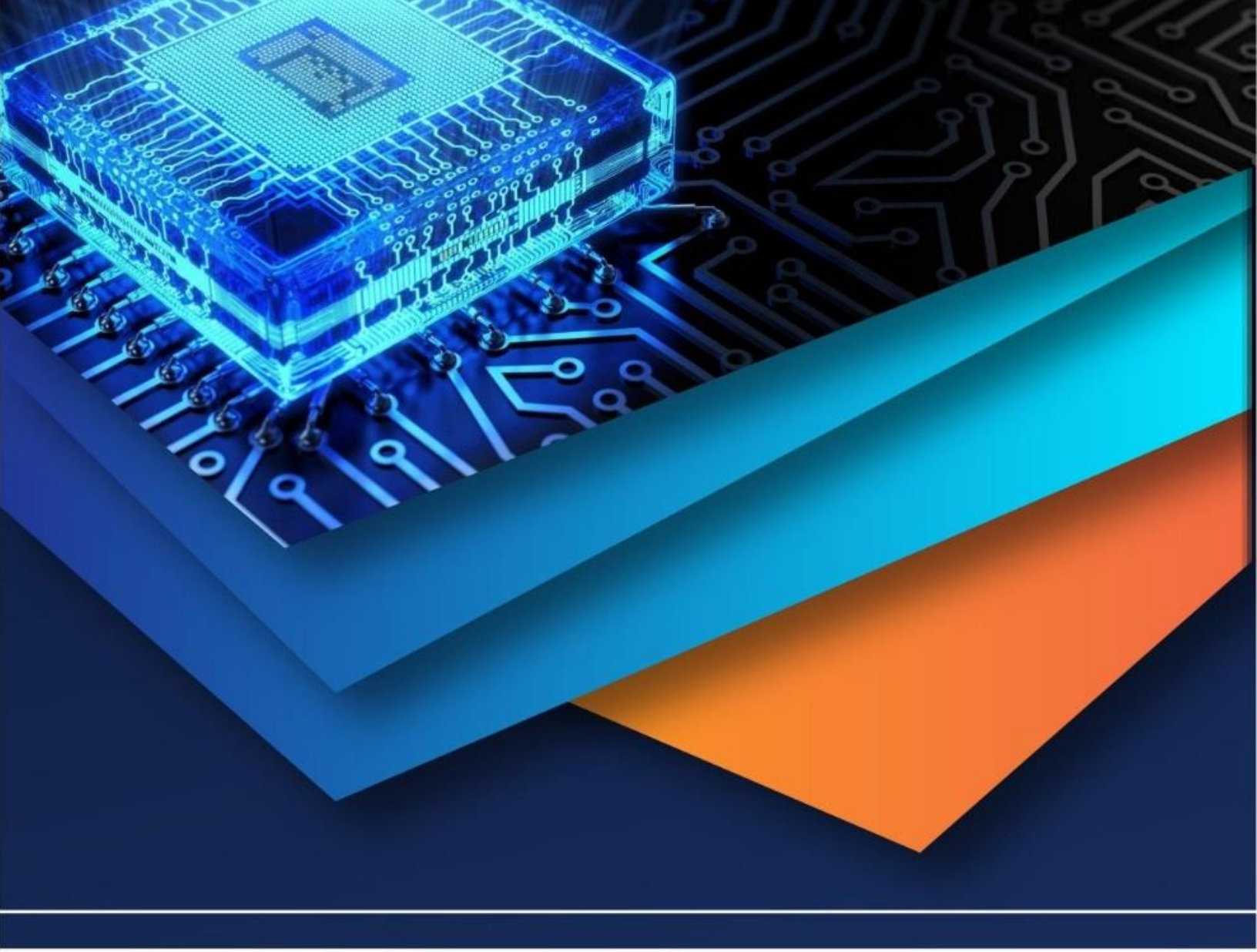
[1] Kim, Dong Yeong, et al. "Prediction of hydrogen concentration in containment during severe accidents using fuzzy neural network." Nuclear Engineering and Technology, vol.47, no.2, pp. 139-147, Mar. 2015.
[2] Bohr, N. and Wheeler, J.A., 1939. The mechanism of nuclear fission. Physical Review, vol.56, no.5, pp.426- 450,Sept. 1939
[3] Krane E, Kenneth S. Oregon state university, Introductory Nuclear Physics, John Wiley & Sons, New York. 1988.
[4] Choi, Geon Pil, et al. "Prediction of hydrogen concentration in nuclear power plant containment under severe accidents using cascaded fuzzy neural networks." Nuclear Engineering and Design vol.300, pp. 393-402, Feb. 2016.
[5] Abou-Rjeily, Y., G. Cénérino, A. Drozd, S. Lee, J. Misak, C. O. Park, G. Preusser, and G. L. C. M. Vayssier. "Mitigation of hydrogen hazards in severe accidents in nuclear power plants." In Technical Report IAEA-TECDOC-1661. 2011.
[6] A. Carboni, E. Ragaini and A. Ferrero, "A fuzzy inference system for power systems," 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI), Modena, 2017, pp. 1-5.
[7] Perfilieva, Irina. "Analytical theory of fuzzy if-then rules with compositional rule of inference." Fuzzy Logic. Springer, Berlin, Heidelberg, pp.174-191, Nov.2007.
[8] Castellano, Giovanna, Anna Maria Fanelli, and Corrado Mencar. "Design of Transparent Mamdani Fuzzy Inference Systems." HIS, pp.468-477, Dec. 2003.
[9] Sugeno, Michio. Industrial applications of fuzzy control. Elsevier Science Inc., 1985.
[10] Blahnik, C., et al. "Modular accident analysis program for CANDU reactors." 12th Annual Conference Canadian Nuclear Society Saskatoon, Saskatchewan June 9-12, 1991.
[11] Prošek, Andrej, Iztok Parzer, and Božidar Krajnc. "Simulation of hypothetical small-break loss-of-coolant accident in modernized nuclear power plant." Electrotechnical Review vol.71, no.4, pp. 199-204, Oct. 2004.
[12] Wellock, Tom. "Putting the Axe to the 'Scram'Myth." The US National Regulatory Commission Blog , 2011.
[13] Choi, Geon Pil, et al. "Estimation of LOCA break size using cascaded fuzzy neural networks." Nuclear Engineering and Technology vol.49, no.3, pp. 495-503, Apr. 2017.
[14] S. H. Lee, Y. G. No, M. G. Na, K. Ahn and S. Park, "Diagnostics of Loss of Coolant Accidents Using SVC and GMDH Models," in IEEE Transactions on Nuclear Science, vol. 58, no. 1, pp. 267-276, Feb. 2011.
[15] Na, Man Gyun, et al. "Estimation of break location and size for loss of coolant accidents using neural networks." Nuclear Engineering and Design vol.232, no.3, pp. 289-300, July 2004 .
[16] M. G. Na, W. S. Park and D. H. Lim, "Detection and Diagnostics of Loss of Coolant Accidents Using Support Vector Machines," in IEEE Transactions on Nuclear Science, vol. 55, no. 1, pp. 628-636, Feb. 2008.
[17] Hong, Seong-Wan, et al. "Research efforts for the resolution of hydrogen risk." Nuclear Engineering and Technology vol.47, no.1, pp.33-46, Jan. 2015.
[18] Agrawal, Nilesh, Aneesh Prabhakar, and Sarit K. Das. "Hydrogen distribution in nuclear reactor containment during accidents and associated heat and mass transfer issues—a review." Heat Transfer Engineering vol.36, no.10, pp. 859-879, Sept. 2014.
[19] Park, Kweonha, and Khor Chong Lee. "Proposal and Analysis of Hydrogen Mitigation System Guiding Hydrogen in Containment Building" Journal of the Korean Society of Marine Engineering, vol. 39, no. 5, pp. 516-521, Jan. 2015.
[20] Smith, Curtis, Scott Beck, and Bill Galyean. Separation requirements for a hydrogen production plant and high-temperature nuclear reactor. No. INL/EXT-05-00137. Idaho National Laboratory (INL), 2005.
[21] Naterer, Greg F., Ibrahim Dincer, and Calin Zamfirescu. "Nuclear Energy and Its Role in Hydrogen Production." Hydrogen Production from Nuclear Energy. Springer, London,pp.21-64, Jan.2013.

Mohammad Sibgat Ullah is an Ex-Master's student in the Department of Electrical Engneering, Jamia Millia Islamia, New Delhi. He has completed M.tech (2017-2019) in Control and Instrumentation System at the Department of Electrical Engineering, Jamia Millia Islamia. He has completed his B.Tech (2013-2017) in Electronics and Communication Engineering from Shri Mata Vaishno Devi University, Katra, Jammu and Kashmir, India.
Email: sibgat.ullah@outlook.com
Phone: +918825077920
Postal Address: Lane No.10, Aribagh Kanipora, Nowgam-Byepass, Srinagar, Jammu and Kashmir- 190015.

Asif Hamid Bhat is an Ex-Master's student in the Department of Electrical Engneering, Jamia Millia Islamia, New Delhi. He has completed M.tech (2017-2019) in Control and Instrumentation System at the Department of Electrical Engineering, Jamia Millia Islamia.

Shabana Mehfuz is a Professor at the Department of Electrical Engineering, Jamia Millia Islamia, New Delhi.

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)