International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 06, June-2015

Fault Prediction based on Neuro-Fuzzy System

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***Abstract*—It is very important to predict fault of machine well in advance so this paper proposes system or method to predict the fault and for that using the combination of statistical methods, artificial neural network (ANN) and fuzzy logic. Artificial intelligence in this case ANN and fuzzy will help to detect fault before it occurs in machine. Continuously analyzing the data produces by machine it may be form of table, graph or any other form. The defect or fault of machine must be affects on result it produces so by reading or by identifying some parameters it is possible to detect fault well in advance. Multilayer backpropagation algorithm of ANN will travels the input through different layers and produces output if error is there then back propagate and change weights accordingly. This output gives to the fuzzy and provide fuzzy rules to take decision of fault. Fuzzy will determine how much fault is there is it tolerable or not. ANN provide behavior of different parameters by continuously analyzing the result of machine and determine there is any effect on components of machine by using parameter values and it will then provide to the fuzzy. The Neuro-fuzzy system (NFS), after training with machine condition data, is employed as a prognostic model to forecast the evolution of the machine fault state with time. NFS residuals between the actual and predicted condition data.**

***Keywords*—Artificial neural network, fuzzy logic, backpropagation algorithm, multilayer network.**

I. INTRODUCTION

In recent years modern industrial system focuses on state based maintenance due to increased complexity and criticality of instruments. Instead of traditional breakdown system in which fault was known only if it occurs and then took appropriate action on fault, the main disadvantage of that system it wastes production time of machine as fault or defect was known only if it occurs in system. It will avoid dreadful failure. Mainly this maintenance focuses on the data collection, data handling, finding behavior, fault detection parameters and fault prediction. In this the fault prediction plays very important and critical role. The task of fault prediction is to accurately and surely tell about future of machine or machine component and also told to the user the remaining life of that particular component. If prediction is wrong or not precise it will directly effect on productivity, efficiency and also industries reputation and work. It lots mean to the industry. In prediction fault must be known before it occurs so there is no future observations only the strong intelligence support for this type of decision making system.

Artificial neural network (ANN) is inspired by biology specifically the working of brain. Depending upon training and leaning human brain works and collectively by applying previous knowledge and some statistics brain will take the decision. Human brain connections and structure is very complicated and critical it is highly impossible to create such type of network or system. ANN is only simplest form of that where there is working unit called as “neuron” which connected to other neurons there are different terminologies which used as it is from biological definitions like dendrites, axle etc. Neuron is main computation unit and accordingly layers of neurons are created to add intelligence in system. To train ANN different training algorithms are available similarly for learning. The basic work of ANN is to give weights to input then by applying sigmoid, tan etc. functions and threshold take the decision. Mostly feed forward networks are used to train the NN and popular leaning algorithm is back propagation which back propagates the error and update accordingly. There are so many applications where ANN is used very widely like face recognition, sale forecast, share market prediction, pattern recognition, medical prognosis and many more.

Fuzzy logic is technique or method where degree of membership for output. It gives the partial membership for particular output in some class. Fuzzy logic build or implemented using fuzzy rule and then by doing fuzzification, rule application and defuzzification it will form overlapping space like triangle, trapezoid etc. So in this case ANN will output into Boolean either true or false and to check the partial fulfillment fuzzy will be used. First statistical method will find the appropriate behavior of parameters’ then ANN will take input from this and find out the fault in any component is present or not and finally fuzzy will identify severity of that fault and pass precise decision to user about replacement or change of component .

In this work ANN will identify the exact fault is present or not and fuzzy will determine the occurred fault is within tolerable limit or not. If it is not in tolerable limit t6hen will give message or decision to user for its change or its fault and all this decision is well in advance before actual fault occurs.

II. MOTIVATION

Nowadays it's very important and efficient for productivity of machine and ultimately industry performance and productivity. In traditional fault management need to repair after breakdown if user have extra component in spare even though it will take time to change and for that moment work or production stops and it happens when it is automatically running on field without any supervisor for some time then it was costs a lot.

To take decision well in advance is not present in existing system. In existing system fault is known only if it occurs and then need to take appropriate action on that there is no any provision to predict fault. In existing system there is neither artificial neural network implemented nor fuzzy logic to take intelligence decision regarding fault detection well in advance. If it predict before someday then will get the time to think and took appropriate decision it will increase efficiency.

III. RELATED WORK

Chaochao Chen, Bin Zhang, and George Vachtsevanos propose a system for prediction based on neuro-fuzzy systems (NFSs) and Bayesian algorithms. They train ann with machine data and then predict the fault. Predicted data used as a input to next Bayesian algorithm to improve the belief. When new data reads or comes again they will update the weights and again training continues and prediction carried out. They considered different models of artificial network and made comparison between all and then find out NFS gives best or appropriate prediction of fault. They have tested this system on faulty bearing and cracked carrier plate [1].

William Hand Allen proposed, for Smart Grids , as per they for the appropriate action need to automatic detection and cataloging faulty or abnormal situations. The application of computational aptitude tools to a heating ventilation and air conditioning for fault detection and fault diagnosis. They uses fuzzy logic to identify different fault signs and using artificial neural network categorize into fault types. Developed system tested with both simulated and real data for fault signs and categorize into fault types [2].

Machine prediction is a substantial part of state based maintenance and proposes to analyze and keep track the fault so that care or maintenance is easy and one can maintain without disruption of work. It will avoid terrible breakdown which will result into efficiency of machine and improves productivity. In this they trained neuro-fuzzy system with failure data and continuously doing that feed all the failure so as system will predict fault in this they used propagation process [3].

Chafaa, K., Slimane, N. , Boutarfa, develop schme based on the artificial neural network and fuzzy logic as a extension of previous or existed fault detection and diagnosis system. They used robot and sensors and actuator and implemented in matlab. There results showing the faults of sensors and actuators detected and classified very efficiently and accurately. In this they focus on the parameters changes due to fault in sensors and actuators [4].

Nieto Gonzalez and Mendez designed a system to predict fault using statistical process control and fuzzy logic. In statistical process control they have used control charts specifically mean bar and standard deviation. Analyzed historical data and give it to control charts for identifying behavior of data and then fuzzy rules provide on them to take decision. According to them this system reduces errors and improves performance [5].

Marcal and Hatakeyama, K. used fuzzy logic for detection of fault and also for predictive monitoring and planning of breakdown in rotating machine. They have used vibration pattern of wheel as a key parameter to detect and predict fault. Rotating machines are having wheels and they produce vibration. If any fault is there in machine then vibration pattern get changed so by considering this as a fault detection parameter they continuously monitors the pattern and accordingly by using fuzzy rules predict fault [6].

ZeFeng Wang and Zarader, Argentieri, S. proposed system to detect fault in aircraft by using artificial neural network for decision making system in aircraft. They designed fault diagnosis system for same which will be useful for pilots and central system to control. They have also suggested that for better and accurate results ann can be paired with any other intelligence system like genetic algorithm, fuzzy logic [7].

Jian-Da Wu and Li-Hung Fang used artificial neural network combine with Wigner-Ville distribution to detect and diagnose fault for gear-sets. Gear sets frequently used in many industries so it is needed to detect fault cost effectively and as early as possible. They have used vibration and noise signals as fault detection parameters. Artificial neural network trained with different fault occurrences by providing different vibration patterns and noise signals as soon as neural network trained with all possible faults next time it will learn automatically and then detect and diagnose the fault. They have compared some of the neural networks and conclude with general regression neural network will provide better result in their application rather than any other [8].

Hooshmand, R.A., Parastegari, M. and Forghani, Z. designed system called adaptive neuro-fuzzy system. They have discussed some disadvantages of only artificial neural network used for fault diagnosis, also they have mentioned only fuzzy logic also not a sufficient to accurately diagnose or and predict the fault due their limitations. So they used both for accurately fault prediction and as early as possible. First they trained neural network so that it will have some fault patterns and known results and then fuzzy will apply and then they conclude by comparing results with some other model as neuro-fuzzy have solved the problem and performance enhanced [9].

Jose, G. and Jose, V. studied that induction motor is very frequently and commonly used machine in industries so monitoring for faults is one of the necessary system in industry. They have also studied different methods for fault detection and prediction and they ends with soft computing techniques like artificial neural network or fuzzy logic or combinations are the best analyzers for faulty systems. They worked on simulation and study the different faults and then finally successfully implemented system [10].

Adouni, A., Ben Hamed, M., Flah, A., and Sbita, L. established a scheme which works on artificial neural network and fuzzy logic to detect and segregate faults in sensors and actuators. They have used artificial neural network to detect faults of sensors and actuators and used fuzzy logic to segregate them. Developed simulated system and tests the results and they conclude that sensors and actuators faults perceived and isolated accurately and successfully [11].

Rahman, R.Z.A. and Yusof, R. Build a model to detect and diagnose fault of process control rig. Fuzzy logic with genetic algorithm and also artificial neural network used to detect and diagnose fault. Fuzzy logic with genetic are used to optimize the member functions and it detect and diagnose faults. Output of this provides to the artificial neural network to classify the faults because residuals then artificial neural network classify them and finally fault detected successfully [12].

Table 1: Evaluation of related work

Method Used	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Statistical method	N	N	N	N	Y	N	N	N	N	N	N	N
Artificial Neural Network (ANN)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y
Fuzzy Logic	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y

Note: Pi are the reference papers. and Y-Yes and N-No.

IV. PROPOSED SYSTEM

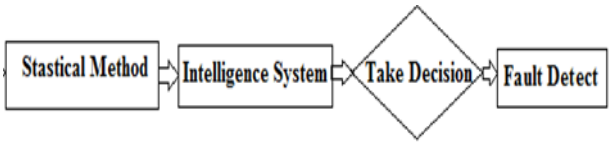

Fig.1: Proposed block diagram

Working Module:

Statistical Methods: This will find the pattern or behavior of data by continuously monitoring and analyzing the result. Applying test it will give the how actually data is behaving i.e. it will give trend is present or not, is data going out of bound etc. The output of this or analysis of this it becomes use by artificial neural network. In statistical methods will going to use mean and standard deviation to calculate and plot.

The Mean, for a data set, the mean is the sum of the observations divided by the number of observations. It identifies the central location of the data, sometimes referred to in English as the average. Equation 1 gives the mean formula.

$$M = \Sigma(X)/N \quad \ldots. \quad (1)$$

Where
Σ X = Sum of Individual data points
N = Sample size (number of data points)

The standard deviation is the most common measure of variability, measuring the spread of the data set and the relationship of the mean to the rest of the data. If the data points are close to the mean, indicating that the responses are fairly uniform, then the standard deviation will be small. Conversely, if many data points are far from the mean, indicating that there is a wide variance in the responses, then the standard deviation will be large. If all the data values are equal, then the standard deviation will be zero. Equation 2 gives standard deviation.

$$S^2 = \Sigma(X\text{-}M) / N \quad \ldots. \quad (2)$$

Where
Σ X = Sum of Individual score
M = Mean of all scores
N = Sample size (number of scores)

Artificial Neural Network (ANN): It will determine from that patterns given by statistical method that exactly fault is occurred or not. E.g. Component is faulty or not is exactly determined by ANN and then again this will provide to fuzzy system.

In this will going to use multilayer feed forward network with backprapagation algorithm. In multilayer network there is one input layer, one output layer and one or more hidden layers. Statistical methods output feeds to this module and it routes through inputs and will identify the accurate or exact fault present or not. Input for this is the behavior of parameters considered for fault detection over the time period. If behavior of parameter is same over the long period then accordingly it will take the decision of fault.

The standard backpropagation algorithm will going to use and algorithm as follows [13]:

1. First apply the inputs to the network and work out the output – remember this initial output could be anything, as the initial weights were random numbers.
2. Next work out the error for neuron X The error is What you want – What you actually get, in other words:
   $Error_X = Output_X (1-Output_X)*(Target_X – Output_X)$
   The "Output *(1-Output)" term is necessary in the equation because of the Sigmoid Function – if we were only using a threshold neuron it would just be (Target –Output).
3. Change the weight. Let W^+_{XY} be the new (trained) weight and W AB be the initial weight.
   $W^+_{XY} = W_{XY} + (Error_X * Output_Y)$
   Notice that it is the output of the connecting neuron (neuron Y) we use (not X). Need to update all the Weights in the output layer in this way.
4. Calculate the Errors for the hidden layer neurons. Unlike the output layer we can't calculate these directly (because we don't have a Target), so we Back Propagate them from the output layer. This is done by taking the Errors from the output neurons and running them back through the weights to get the hidden layer errors. For example if neuron X is connected as shown to Y and Z then we take the errors from Y and Z to generate an error for X.

$Error_X = Output_X (1 - Output_X)(Error_Y W_{XY} + Error_Z W_{XZ})$

Again, the factor "Output (1 - Output)" is present because of the sigmoid squashing function.

5. Having obtained the Error for the hidden layer neurons now proceed as in stage 3 to change the hidden layer weights. By repeating this method we can train a network of any number of layers.

Fuzzy logic: It will access the result from ANN and it will going to find how much it is faulty and then decision will take according to is it within tolerating limit or not if fault is tolerable there is no faulty message sent to user if it is not in tolerable limit the message of fault will send to user for further action. The artificial neural network gives only fault is present or not i.e. yes or no there is no any intermediate result like how much fault is present then how to predict to user that components are need to be change or not because if fault is within tolerable limit in that case also ANN will revert with error. Due to this situation fuzzy logic will useful.

There are mainly three states in fuzzy namely fuzzification in this input values changed into truth values second is rule evaluation in this each truth value evaluated and produce output truth values according to degree of membership in particular class and lastly defuzzification in this again output truth values converted into output.

V. INDENTIFIED METHODS

In statistical method used standard deviation. In artificial neural network feed forward single layer perceptron with backpropagation algorithm and in fuzzy logic max-min decomposition will give better and accurate result.

VI. CONCLUSION

It is very important and necessary for today's critical machines in industry to provide prediction for fault which will improve efficiency as well as productivity without consuming time or without stopping any kind of work. For decision making identified hybrid model of artificial neural network and fuzzy logic which will give accurate prediction of component fault.

If all the three methods applied for the prediction of fault it will give near about correct predictions. In future may me implementation can be do using different combinations of methods to correct, appropriate and exact detection and prediction. In future there will be more critical instruments invented so required to develop flexible system which adapt in any environment.

ACKNOWLEDGMENT

I am very thankful to the Savitribai Phule Pune University, Pune. I am highly grateful to my department and college, Department of computer engineering and Smt. Kashibai Navale College of Engineering to providing all the facilities.

I am thankful to my esteemed guide Prof. S. K. Pathan for expert and precise guidance.

REFERENCES

[1] Chaochao Chen, Bin Zhang, and George Vachtsevanos, "Prediction of Machine Health Condition Using Neuro-Fuzzy and Bayesian Algorithms," in IEEE transactions on instrumentation and measurements, vol. 61, no. 2, pp. 567-577 February 2012.

[2] William Hand Allen and Ahmed Rubaai, "Fuzzy-Neuro Health Monitoring System for HVAC System Variable-Air-Volume Unit", in IEEE IACCA,vol.289, pp. 019-027, May 2013.

[3] Chaochao Chen, Bin Zhang, George Vachtsevanos, "Neuro–Fuzzy and High-Order Particle Filtering" in IEEE transactions on industrial electronics, vol. 58, no. 9, pp. 4353-4364, September 2011.

[4] Chafaa, K., Slimane, N. , Boutarfa, A. " Fault diagnosis in robotic manipulators using artificial neural networks and fuzzy logic" in Computer Applications and Information Systems (WCCAIS),World Congress, vol. 45, pp. 1-6, January 2014.

[5] Montes Dorantes, P.N. ; Nieto Gonzalez, J.P. ; Mendez, G.M. "Fault Detection Systems via a Novel hybrid Methodology for Fuzzy Logic Systems based on Individual base inference and Statistical Process Control",in Latin America Transactions, IEEE (Revista IEEE America Latina), vol.12, no.4, pp. 706-712, June 2014.

[6] Marcal, R.F.M. and Hatakeyama, K., "Expert System based on fuzzy rules for monitoring and diagnosis of operation conditions in rotating machines", in Management of Engineering & Technology (PICMET), Portland International Conference, vol. 788, pp. 577 – 584, July 2014.

[7] ZeFeng Wang, Zarader, J.-L., Argentieri, S. "Aircraft fault diagnosis and decision system based on improved artificial neural networks" in Advanced Intelligent Mechatronics (AIM), IEEE/ASME International Conference, vol. 234, pp. 1123 – 1128, July 2012.

[8] Jian-Da Wu and Li-Hung Fang, "A Fault Diagnosis System for a Mechanical Reducer Gear-Set Using Wigner-Ville Distribution and an Artificial Neural Network" in Computational Science and Its Applications (ICCSA), 13th International Conference IEEE, vol. 465, pp. 170-173, June 2013.

[9] Hooshmand, R.A., Parastegari, M. and Forghani, Z., "Adaptive neuro-fuzzy inference system approach for simultaneous diagnosis of the type and location of faults in power transformers", in Electrical Insulation Magazine, IEEE, vol.28, no.5, pp. 32 – 42, August 2012.

[10] Greety Jose and Victor Jose, "Fault diagnosis in induction motor using soft computing technigues", in International Conference on Advanced computing and communication systems IEEE, vol. 365,pp. 876-882, December 2013.

[11] Adouni, A., Ben Hamed, M., Flah, A. and Sbita, L., "Sensor and actuator fault detection and isolation based on artificial neural networks and fuzzy logic applicated on induction motor" in Control, Decision and Information Technologies (CoDIT), International Conference,vol. 467, pp. 917-922, May 2013.

[12] Rahman, R.Z.A., Yusof, R. and Ismail, F.S., "Model-based fault detection and diagnosis optimization for process control rig" in Control Conference (ASCC), 9th Asian, vol. 589, pp. 1-6, June 2013.

[13] https://www4.rgu.ac.uk/files/chapter3%20-%20bp.pdf