Applications of Artificial Intelligence Models in Power System Analysis

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***Abstract*— Over the past decade, artificial intelligence (AI) technology has been developed and grown in popularity in almost every field of life due to its efficiency, accuracy, strong processing power, intelligence, and sustainability. The aim of AI is to facilitate its human-like capabilities of learning, adapting, and reasoning. Owing to its development, Power Systems has also attracted considerable interest in the direction of AI. With the help of these AI techniques an improvement in Operation and Control, Fault Analysis, Automation of the Power System, Monitoring of the Health Index of the System and many other tasks have been achieved. The purpose of this review paper is to outline the most frequently AI technologies utilized in Power Systems Analysis.**

Keywords—Artificial Intelligence, AI, Power Systems, Fuzzy Logic, Artificial Neural Networks, Genetic Algorithms, Expert Systems

I. INTRODUCTION

The future lies in Artificial intelligence as intelligent machines are replacing and enhancing human capabilities in various fields. In recent years, Artificial Intelligence has taken over many sectors and the Power System is also no different. Artificial Intelligence is one of the most salient research areas nowadays. Its aim is to facilitate the systems where conventional methods fail or are unable to fully meet the demands.

AI possesses tremendous human-like capabilities like learning, reasoning, adapting, and it has been applied in various fields like image and speech recognition, automation, etc. Apart from computer-related fields, AI also refers to Psychology, Philosophy, linguistics, and other disciplines as well [1]. AI is a very broad field and developments take place every now and then. There are a lot of AI techniques but in Power Systems Analysis, some of the AI technologies that have matured enough to the point that they can offer real practical benefits in the fields will be discussed in this paper. Some research on the applications of AI in Power systems has been conducted like fault analysis (detection and diagnosis) been studied in [2,3,4,5,15,17,20] where Artificial Neural Networks and Fuzzy Logic techniques were used, similarly, Genetic Algorithm based techniques to solve different Power System problems were studied in [33,36,37,38,39].

After going through different papers, AI definitely comes out as a really important and powerful tool to solve modern-day problems, and, with the Renewable energy sources utilization growing day by day, it has become even more difficult to create different scenario-based problems and obtain its solution, so AI techniques have the capability to handle those complex, varied and real-time problems as studied in [18,19,26,28,39,40]. Henceforth, AI techniques aid in handling vast data systems, and in solving real-time-based problems providing accurate solutions with fast processing power and efficiency.

II. ARTIFICIAL NEURAL NETWORK (ANN):

All definitions of Artificial Neural Networks emphasize the concept of highly linked units made up of basic nonlinear parts. [2]. ANN is an adaptive non-linear statistical model identification technique. Most of the ANN models are designed by trial and error methods. As this method is not very efficient, the probability of successful training is low. To counter this problem, the number of training cases is increased than the number of parameters that are to be determined. ANN has been a powerful tool and is widely used in many applications due to its robustness, ability to handle incomplete data sets, fault tolerance, and the capability to generalize.

A. Principle:

Artificial Neural Networks (ANN's) are biologically roused systems in which a network of neurons is used to turn a set of inputs into a set of outputs, with each neuron providing one output as a function of inputs. The basic functional unit of the neuron is shown in figure 1.

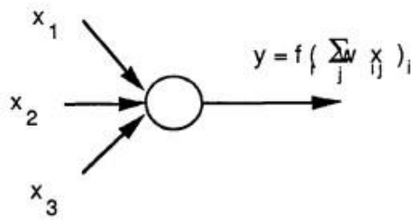

Fig. 1. Structure of a neuron

ANN is implemented by training it under the supervision and by feeding it with inputs. After it is sufficiently trained it can solve different problems other than those that it was trained to solve for. As it is a generic sort of AI, it very much resembles the working of a human brain. ANN models are usually classified by their architecture, number of layers, connectivity patterns, and feed-forward or recurrent. In power systems, Multi-Layered Feed Forward based ANN models

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are mostly used. The layers of the ANN model are:

1. Input Layer: Input parameters are given in this layer; however, this layer does not process the data or the information, it just distributes the data to others. The outputs of the input layer are used as inputs to the next hidden layer.
2. Hidden Layers: This layer is hidden and it helps the system to recognize the problems.
3. Output Layer: This layer consists of the output values, which are to be allocated to the case under study.

A multi-layered ANN model is shown in figure 2.

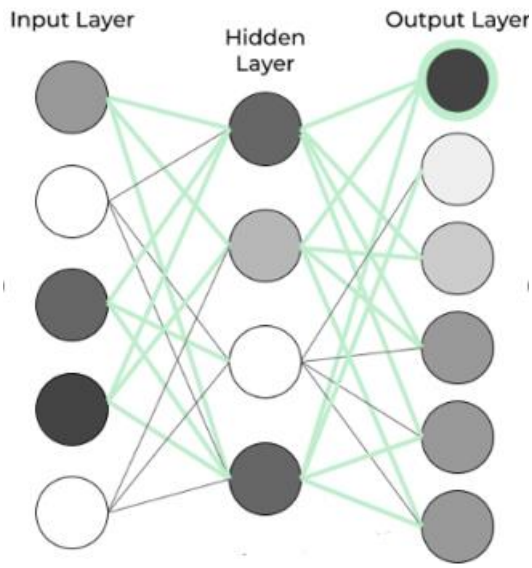

Fig. 2. Multi-Layered Feed-forward Neural Network

ANN, particularly for Power system cases, is used where quick results in real time are required as it possesses the ability to quickly generate results once input is received. Also, the problems requiring the encoding of a non-linear function are well-suited for ANN.

B. Applications;

ANN has been used in Power System Analysis by utilizing it in the following tasks:

- Fault Analysis (Locating, detecting, etc.) [1,2, 3, 4, 17, 20,40]
- Voltage Stability Analysis [1,2, 3, 4, 6, 17]
- Maintaining the Dynamic Stability of the system [1,2, 3, 4, 6, 9, 20]
- Operations and Control (Unit Commitment, Optimal Power Flow, Speed Control System, etc.) [1,2,11,16,21,31]
- Planning/Forecasting (Short-term/long-term load forecasting) [11,12,16,21]

III. GENETIC ALGORITHMS (GA):

Genetic Algorithms are a sub-division of the Evolutionary Computing AI technique [39]. A genetic Algorithm is a technique that is based on optimization. Genetic Algorithm, as the name suggests, solves problems by the analysis of genes of a system. So, it is widely used to solve optimization problems (both constrained and unconstrained), load flow problems and problems related to operation in Power System Analysis. GA is used due to its robustness and ability to provide accurate solutions.

A. Principle:

The main principle behind GA is "survival of the fittest" or, in other words, only the fittest member of a system has the highest probability to survive [22]. This unique feature makes it different from other techniques. It only uses objective function information and uses probability transition laws. GA uses a simple model of population genetics with five components i.e. an initial population, evaluation function, genetic operators, values for the parameters, chromosomal representation of variables. These things help the algorithm quickly find an approximate and nearly accurate solution to the problem. Within a framework, GA develops a solution by means of binary strings.

These strings are composed of sub-strings, each of which stands in for a distinct variable. For instance, if a sub-string is 4 bits long, as [1 0 l 1], it may represent 16 distinct values [19]. GA terminology refers to the bits as "genes" and the entire string as a "chromosome". A "population" is made up of numerous chromosomes and each chromosome represents a distinct solution.

B. Applications;

GA is being used in Power System Analysis to counter the following:

- Load Flow Problems [36, 37, 38, 39]
- Economic Dispatch Problems [1, 7, 8]
- Optimal Power Flow [1, 37,38]
- Power System Distribution, Planning, and Control [16, 37,38,39]
- Clustering of Power systems [19, 20, 27]

IV. FUZZY LOGIC (FL):

In 1964, Lotfi Zadeh developed FL to address inaccuracy and uncertainty which usually exist in engineering problems [10]. Fuzzy logic, also known as Fuzzy Systems, is a logical method for formalizing and standardizing approximate reasoning. FL is also very much similar to human decision-making ability as it can produce almost accurate solutions from an approximate information set. FL provides us with an improved capability of modelling complex problems along with providing ambiguity throughout the analysis of a system. Uncertainties in issue formulation can be articulated and processed using fuzzy systems theory. Fuzzy regression models, statistical decision-making utilizing fuzzy probability and fuzzy entropy, fuzzy quantification theory, and other applications employ fuzzy systems. In Power Systems, FL is applied where the data set contains uncertainty or where logical reasoning is required. Fuzzy logic is used to convert numerical to symbolic inputs and back again for outputs. Fuzzy algorithms are relatively easy to execute because of their similarities with regular language, but they may need extensive verification and testing. Fuzzy logic mathematics may also be utilized to assist analysts in creating automatic buy and sell signals in certain advanced trading algorithms. These technologies assist investors in responding to a wide range of shifting market circumstances that impact their assets.

A. Principle:

Fuzzy logic is a heuristic approach that allows more advanced decision-tree processing and improved integration with rules-based programming. It uses the "IF-THEN" logic that converts an input fuzzy set to an output fuzzy set. FL is a code designed to control something. Adaptive fuzzy controllers can adapt to changes and learn how to control complex processes much as a human does. It has five stages of implementation:

1. Defining fuzzy variables
2. Applying the operators(OR,NOT,AND) in the IF-THEN rule
3. Implementation of IF-THEN logic (Control)
4. Obtaining fuzzy value
5. De-fuzzification

The different stages of Fuzzy Logic implementation are shown in figure 3.

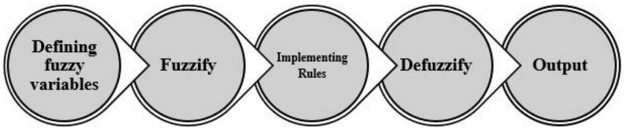

Fig. 3. Implementation Stages of Fuzzy Logic

B. Applications;

FL has been used in Power System Analysis by utilizing it in the following tasks:

- Analysing the stability of the system [1, 7, 9, 17, 37, 38, 39]
- Enhancing and optimization of the system [11, 16, 36, 37, 38, 39]
- Controlling the system [22, 37, 38, 39]
- Complete Fault Analysis [23, 37, 38, 39]
- Assessing the overall security of the system. [13, 15, 28, 39]
- Load forecasting (short/long term) [18, 21, 28, 29,39]
- Reactive power planning [24, 37]

V. EXPERT SYSTEMS (ES):

Expert systems are the oldest AI technique and are well known for their ability to obtain knowledge from a human expert in a specified domain and convert it into machine-usable form. ES are basically computer programs that have sufficient grip in a particular field. Its knowledge is generally stored in form of rules, models, frameworks, etc. ES uses its knowledge and capabilities to solve problems that are unsolvable or extremely difficult to get a solution to. ES is very consistent with its techniques, and can be easily documented, transferred, and reproduced, however, ES unlike other AI techniques, is not able to adapt itself to new scenarios. The architecture of ES has the following components:

1. A Knowledge Base: It contains the facts and rules.
2. A Component that helps solve the problems: This component helps develop a problem-solving strategy
3. An explanation component: Helps explain the problem-solving steps
4. Knowledge acquisition Component: The AI component, helps adapt and implement new knowledge.
5. Dialogue Component: Communication component between the user and the computer.

A. Principle:

ES uses the IF-THEN rules after it integrates the expert knowledge in a Boolean logic catalogue. It answers the why-and-how-based scenarios which can be updated continuously. The basic elements of ES are shown in figure 4.

Fig. 4. Elements of Expert Systems

B. Applications;

ES are rarely being used where the following tasks are to be accomplished:

- Decision Making
- Solution of problems by heuristics, reasoning, and/or judgment

So, for Power System Analysis, it is used in the following areas:

- Power System Operations [1,16,17,20]
- Power System Planning [1,29,31]
- Power System Diagnostics [1,2,3,27]

VI. CONCLUSIONS

This paper provides insight into the Artificial Intelligence Techniques being used in Power System Analysis. AI techniques are used where conventional methods fail to provide accurate results. A lot of research is being carried out to utilize the abilities and capabilities of AI techniques in Power System Applications and Analysis. Some of the AI techniques which have matured enough to provide practical benefits like Artificial Neural Networks, Fuzzy Logic, Genetic Algorithms, and Expert Systems were reviewed along with their applications in Power Systems. Each technique has its own pros and cons and specific areas where they can be utilized effectively. AI techniques are particularly useful in planning, controlling, and forecasting activities. It is very important to study and identify the techniques that can be utilized for a particular problem. However, plenty of research is yet to be performed to manifest the technology for improving the overall performance of Power Systems.

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