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ARTIFICIAL INTELLIGENCE IN ELECTRICAL ENGINEERING

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Abstract*— This paper aims to study about artificial intelligence, different techniques, implementation of these techniques to solve the problems related to electrical engineering, that are aimed towards increase of accuracy, efficiency. Access to electricity is an indication of economic growth and living standards of people. A continuous, reliable supply of electricity is necessary for functioning of today's modern, advanced society, where the demand is increasing day by day. Planning and operation of power system aims to provide reliable and continuous power. Load flow analysis, security, stability, contingency, voltage and reactive power control are some of the key issues to be assessed and monitored continuously. The practical conventional methods used for the assessment and analysis are iterative, unreliable and time consuming. With the development of science and technology, most of the efforts are made in the electrical field that has turned away the methodology of formal mathematical numerical analysis of different problems in generation, transmission and distribution, to a less rigorous, less tedious, stable, computational efficient and scalable techniques of Artificial intelligence techniques. Artificial intelligence techniques have been visualized as an effort to emulate the ability of humans to think rationally, process information in order to reach conclusive results.*

Keywords — Artificial intelligence, Electrical engineering, ANN, fuzzy logic, Expert system, Genetic algorithm.

I. INTRODUCTION

Artificial intelligence is a scientific discipline aiming to research, develop and simulate human behavior and its rules. Artificial intelligence techniques including Brain Science, Neurology, information technology and various discipline artificial intelligence techniques including Brain Science, Neurology, and disciplines such as information technology, widely used in all walks of life, through to mimic the behavior of the human brain, developed a way to replace human brains, discover, identify and analyze machine, improve efficiency and save money. Artificial intelligence has provided a great potentialand space for optimization in the field of electrical engineering. This can not only bring about a significant improvement not only with regards to the economic aspects but also in the safety and the actual control of the operation. Ever since artificial intelligence reached a stage where it could be used in various fields in order to make work simpler, it has been used widely in various fields of life, primarily in robotics and computer programming. Recent studies and investigations have shown that artificial intelligence can also be a viable option in the field of electrical engineering especially as a solution to some long-standing power system problems where conventional methods experience some difficulty.

II. PROS AND CONS OF ARTIFICIAL INTELLIGENCE

As an emerging technology, artificial intelligence has its fair share of advantages and disadvantages. By studying more about the pros and cons of artificial intelligence, we can decide on how artificial intelligence can be integrated with electrical engineering in orderto facilitate a smarter system.

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A. Pros of Artificial Intelligence

- **Reduction in human error:** With the increase in the amount of data being supplied, artificial intelligence can completely nullify human error and thereby give a much more accurate result when compared to the results provided by humans. [1]
- **Safety:** Artificial intelligence is the fact that human beings do not have to directly interact with scenarios that can be risky or pose a threat to the labor [1]. In case of a fire in an apartment, robots powered by AI can be used to navigate through the building and put out the fire, thereby nullifying the risk to human life as well as accomplishing the task with a satisfactory outcome.
- **Repetition:** There are a lot of tasks that need to be repeated in order to be completed [1]. Artificial intelligence can be used in order to tackle such tasks with ease, thereby not only completing the task but also ensuring that human labor is not wasted on such tasks. A possible area of application can be in the manufacturing and automation of various electrical components.
- **Decision making:** The main difference between artificial intelligence and human intelligence is that human beings analyze all the factors pragmatically as well as emotionally and then come to a decision based on what that person feels is right. Artificial intelligence on the other hand gives an output considering all the factors based on how it has been programmed. This approach significantly speeds up the problem solving and decision making.
- **Availability:** Artificial intelligence is available the whole day owing to the fact that it is a computer program that analyzes the various inputs being provided to the system [1]. Robots and machines that make use of artificial intelligence do not tire like humans thereby increasing the cumulative hours of work put in as well.

B. Cons of Artificial Intelligence

- **Unemployment:** There is a fraction of people who believe work will be made easier with the adoption of artificial intelligence in a lot of fields but there are people who believe that artificial intelligence can replace human labour in these fields, thereby eliminating the need for humans.
- **Propagation of laziness:** Artificial intelligence is not only available 24x7 but also does not tire and perform at peak efficiency all day [1]. This eliminates the need for human supervision as well, thereby making us complacent and lazy as we feel that the artificial intelligence can deal with the problems at hand.
- **Lack of emotional intelligence:** Artificial intelligence solves problems and makes decisions much faster than human beings but this comes at a cost [1]. Artificial intelligence just does as programmed and programming of emotions will take a lot of study, research and effort from scientists all over the world.
- **Cost:** Integrating artificial intelligence into an already existing system not only consumes a lot of time and effort but also costs a lot of money [1]. This means that there is a requirement for a capital amount that needs to be invested.
- **Time of implementation:** Due to a lack of extremely skilled programmers and the difficulty in the development of a satisfactory model, developing the suitable artificial intelligence in order to tackle real [1].

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III. ARTIFICIAL INTELLIGENCE TECHNIQUE

Machine learning focuses on the intricacy of modeling or building programs that learn from experience in simple words. Generally, the representation of knowledge and the algorithms for argumentation about such knowledge is addressed with artificial intelligence, while machine learning is an interdisciplinary research area which incorporates knowledge from different fields, extracts knowledge from experience gathered solving problems to be used to answer unseen examples of similar questions [9]. The primary purpose of machine learning research is the development of fast-response learning methods able to provide automatic information learning from raw data and to implement advanced prediction models used in the decision-making process. Deep learning is the most well-known machine learning subset, due to the unique ability of deep learning that makes it different from other basic models. If a standard machine learning algorithm reflects an imprecise prediction, then it is required to make some manual adjustments by its designer. Nevertheless, deep learning algorithms can automatically conclude if a forecast is accurate or not. Fig. 1 illustrates that deep learning is a subset of meaning learning while it is a subset of artificial intelligence.

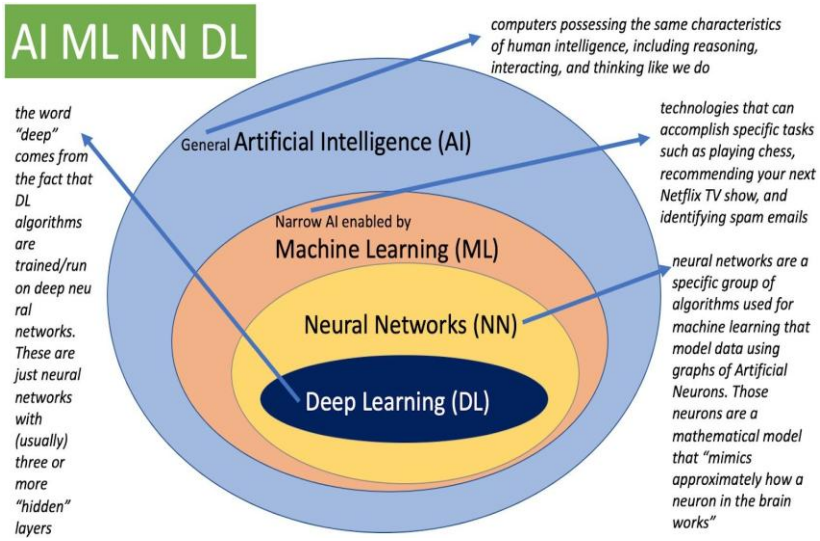

Fig. 1 Distinction between various Artificial Intelligence Methods

IV. ARTIFICIAL INTELLIGENCE METHODS

Modern artificial intelligence technologies include:

A. Artificial Neural Networks

Artificial Neural Networks are biologically inspired systems which convert a set of inputs into a set of outputs by a network of neurons, where each neuron produces one output as a function of inputs as shown in Fig.2. A fundamental neuron can be considered as a processor which makes a simple nonlinear operation of its inputs producing a single output [8]. The understanding of the working of neurons and the pattern of their interconnection can be used to construct computers for solving real

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world problems of classification of patterns and pattern recognition.

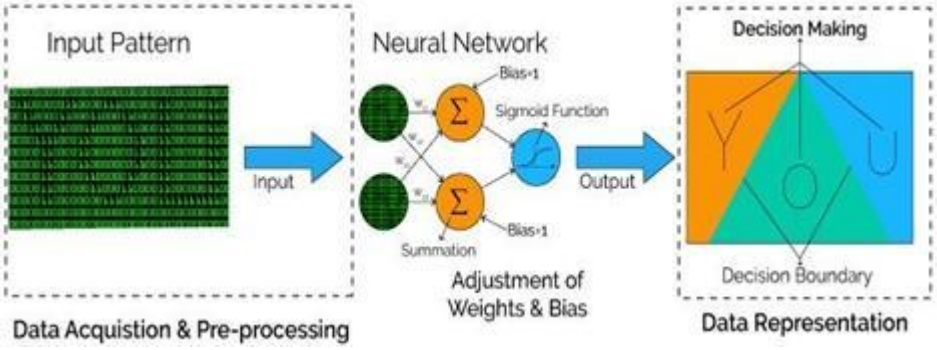

Fig. 2 Artificial Neural Network

Advantages of Artificial Neural Networks (ANN)

1. Problems in ANN are represented by attribute-valuepairs.
2. ANNs are used for problems having the target function, the output may be discrete-valued, real-valued, or a vector of several real ordiscrete-valued attributes.
3. ANN learning methods are quite robust to noise in the training data. The training examples may contain errors, which do not affect the final output.
4. It is used where the fast evaluation of the learnedtarget function is required.
5. ANNs can bear long training times depending on factors such as the number of weights in the network,the number of training examples considered, and the settings of various learning algorithm parameters.

Disadvantages of Artificial Neural Networks (ANN)

I. Hardware Dependence:
   1. Artificial Neural Networks require processors with parallel processing power, by their structure.
   2. For this reason, the realization of theequipment is dependent.

II. Unexplained functioning of the network:
   1. This is the most important problem of ANN.
   2. When ANN gives a probing solution, it doesnot give a clue as to why and how.
   3. This reduces trust in the network.

III. Assurance of proper network structure:
   1. There is no specific rule for determining thestructure of artificial neural networks.
   2. The appropriate network structure is achievedthrough experience and trial and error.

IV. The difficulty of showing the problem to the network:
   1. ANNs can work with numerical information.
   2. Problems have to be translated into numericalvalues before being introduced to ANN.This

is dependent on the user's ability.

V. The duration of the network is unknown:

1. The network is reduced to a certain value of the error on the sample means that the training has been completed.
2. The value does not give us optimum results.

B. Fuzzy logic

Fuzzy logic or Fuzzy systems are logical systems for standardization and formalization of approximate reasoning. It is similar to human decision making with an ability to produce exact and accurate solutions from certain or even approximate information and data [3]. The reasoning in fuzzy logic is similar to human reasoning. Fuzzy logic is the way the human brain works, and we can use this technology in machines so that they can perform somewhat like humans. Fuzzification provides superior expressive power, higher generality and an improved capability to model complex problems at low or moderate solution cost. Fuzzy logic allows a particular level of ambiguity throughout an analysis. Because this ambiguity can specify available information and minimize problem complexity, fuzzy logic is useful in many applications.

Advantages of Fuzzy Logic System

- The structure of Fuzzy Logic Systems is easy and understandable
- Fuzzy logic is widely used for commercial and practical purposes
- Fuzzy logic in AI helps you to control machines and consumer products
- It may not offer accurate reasoning, but the only acceptable reasoning
- Fuzzy logic in Data Mining helps you to deal with the uncertainty in engineering
- Mostly robust as no precise inputs required
- It can be programmed to in the situation when feedback sensor stops working
- It can easily be modified to improve or alter system performance
- inexpensive sensors can be used which helps you to keep the overall system cost and complexity low
- It provides a most effective solution to complex issues

Disadvantages of Fuzzy Logic System

- Fuzzy logic is not always accurate, so the results are perceived based on assumption, so it may not be widely accepted.
- Fuzzy systems don't have the capability of machine learning as-well-as neural network type pattern recognition
- Validation and Verification of a fuzzy knowledge-based system needs extensive testing with hardware
- Setting exact, fuzzy rules and, membership functions is a difficult task
- Some fuzzy time logic is confused with probability theory and the terms.

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Applications of Fuzzy Logic System

Fuzzy logic has been used in numerous applications such as facial pattern recognition, air conditioners, washing machines, vacuum cleaners, anti-skid braking systems, transmission systems, control of subway systems and unmanned helicopters, knowledge-based systems for multi-objective optimization of power systems, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, and stock trading. Fuzzy logic has been successfully used in numerous fields such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics, and optimization [5].

C. Expert systems

Expert system is a kind of intelligent computer software system which is built by human experts. Various components of ES are shown in Fig. 3. It contains a large amount of professional knowledge and rich experience in the power system. Its use has penetrated into all fields [2] especially in the field of artificial intelligence technology and even exceeding the level of human experts. In medical diagnosis, geological exploration, culture and education has been equipped with the corresponding knowledge and procedures of the system and the problem of solving and processing has been close to the level of experts.

The components of ES include −

- Knowledge Base
- Inference Engine
- User Interface

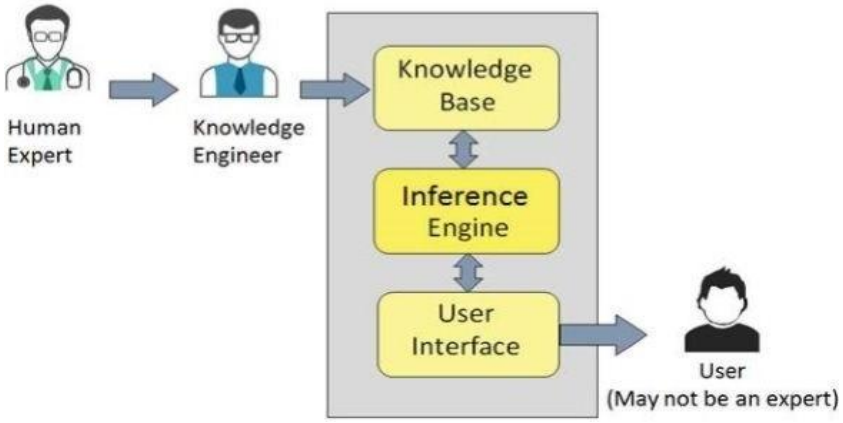

Fig. 3 Expert Systems

The following table shows where ES can be applied.

- Information management
- Hospitals and medical facilities
- Help desks management
- Employee performance evaluation
- Loan analysis
- Virus detection

- Useful for repair and maintenance projects
- Warehouse optimization
- Planning and scheduling
- The configuration of manufactured objects
- Financial decision-making Knowledge publishing
- Process monitoring and control
- Supervise the operation of the plant and controller
- Stock market trading
- Airline scheduling & cargo schedules

D. Genetic algorithms

Genetic algorithm is derived from an elementary model of population genetics. Genetic algorithm works on the coding of the variables set instead of the actual variables. These algorithms look for optimal points through a population of possible solution points, and not a single point [4]. Objective function information and probability transition laws are used for potential solution. It has the following components:

- Chromosomal representation of the variable describing an individual.
- An initial population of individuals.
- An evaluation function which plays the environment's part, ranking the individuals in terms of their fitness which is their ability to survive.
- Genetic operators which determine the configuration of a new population generated from the previous one by a procedure.
- Values for the parameters that the GA uses.
- Areas of applications in power systems include:
- Planning – Wind turbine positioning, reactive power optimization, network feeder routing, and capacitor placement.
- Operation – Hydro-thermal plant coordination, maintenance scheduling, loss minimization, load management, control of FACTS.
- Analysis – Harmonic distortion reduction, filter design, load frequency control, load flow.

V. APPLICATIONS OF AI IN ELECTRICAL ENGINEERING

As discussed, several problems in power systems cannot be solved by conventional methods owing to the fact that the electrical engineering is a highly specialized branch, it requires the use of expert systems in order to solve problems by employing decision making, archiving knowledge, and solving problems by the help of reasoning, judgement and heuristics.

Fuzzy logic systems can primarily be used in fault diagnosis. Assume that a fault has occurred on the transmission line. The fault determination in transmission lines can feed the information of this fault into the fuzzy logic system. The fuzzy system then processes this information in order to give us a crisp output of what the fault is.

Artificial neural networks can be used in improving the performance of the transmission lines.

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Various sensors can be added to the environment and other ambient conditions. These conditions can then be fed into the artificial neural network in order to process it and then change the line parameters in order to improve the performance of the line. The improvement in performance is directly proportional to the efficiency of the ANN. The efficiency and speed of operation of the ANN can be improved by increasing the number of hidden neuron layers in the ANN.

Areas of applications in power systems include:

- Operation of power systems like unit commitment, hydro-thermal coordination, economic dispatch, congestion management, maintenance scheduling, state estimation, load and power flow [1].
- Planning of power systems like generation expansion planning, power system reliability, transmission expansion planning, reactive power planning.
- Control of power systems like voltage control, stability control, power flow control, load frequency control.
- Control of power plants like fuel cell power plant control, thermal power plant control.
- Control of network like location, sizing and control of FACTS devices.
- Electricity markets like strategies for bidding, analysis of electricity markets.
- Automation of power systems like restoration, management, fault diagnosis, network security [2].
- Applications of distribution systems like planning and operation of distribution systems, demand side response and demand side management, operation and control of smart grids, network reconfiguration.
- Applications of distributed generation like distributed generation planning, solar photovoltaic power plant control, wind turbine plant control and renewable energy resources. Forecasting applications like short term and long-term load forecasting, electricity market forecasting, solar power forecasting, wind power forecasting [1].

A. Concept of Transient Protection

Transient protection through detection of transient high frequency models for power system transmission line and power system to realize its own functions, the fault transient models include a lot of fault type, position, direction, duration, and so on. First of all, we must use the specific high-frequency detection device and algorithm to extract the high frequency signal from the fault model then use the special fast signal processing algorithm to determine what kind of fault. The transient protection including high frequency detection, fault identification, transient protection and transient adaptive reclosing these parts, switching in power system fault, lighten can generate high frequency signal, and transmission in the power system, a high frequency detector in the outlet line can detect the identification of non-fault disturbance. When fault happening through fault protection, non-communication protection, transient protection principle to determine whether protection for area fault, if is, tripping and then enter Adaptive reclosing unit, after tripping in high frequency signal analysis to identify whether the fault is a permanent fault, if it is not to close.

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B. Application of Artificial Intelligence in Transient Protection

The application of artificial intelligence mainly includes the application of expert systems, the application of artificial neural networks, fuzzy set theory and genetic algorithms. But in the study of transient protection, it is used in the following two ways: the protection of an expert system and fuzzy logic protection.

- Based on the expert system (system Expert) relay protection. The expert system has been applied in the power system for many years, but because of the protection of power system has strict requirements on reaction time, so the existing expert system is applied to the time required for protection is not very strict, such as: the choice of protection setting, fault diagnosis and fault location. This paper introduces the expert system used in relay protection setting calculation, through the general rules, comprehensive, comprehensive consideration of relay protection system setting involves the problem, to solve the contradictions of setting conflict.

C. Fuzzy Logic Protection

The variation of power system load is varied, such as the change of load, the diversification of power system network structure such as high voltage direct transmission, flexible transmission and series capacitor compensation. The relationship between the structure and components of these systems are very complex, which increases the difficulty of protecting, when disturbance occurs because of the above factors, there are too many uncertainties, not well defined and determined, so the input and output in the protection phase and the intermediate model system has fuzziness. It is precisely just because this fuzziness is closer to the actual characteristics, all of the conditions are given to consider closer to the practical application. fuzzy method is also used to diagnose transformer fault, and the high frequency signal generated by partial discharge and the change of chemical composition in transformer are established. The fuzzy set is established, and the protection of the transformer is achieved. But it is difficult to model the fuzzy technology, so it is often combined with a neural network, and the neural network is composed of a large number of individual neurons in a certain way [7]. A single neuron is cover input to output transfer function of nonlinear functions, and the combination of a large number of neurons and the achievement is very complex and nonlinear, and carries a lot of weight on the implicit in the information which can be achieved by adjusting the weights of neural network from the complex nonlinear mapping of artificial neural network m to N dimensions are widely used for transient protection fault diagnosis and fault line selection. Fast and accurate, and is not affected by the system operating mode, fault type, transformer saturation and other factors; for non-communication protection, can extract the fault frequency signal, obtain good simulation results; for lightning wave, identification, switching operation and fault traveling wave is easy to converge.

Several problems in power systems cannot be solved by conventional techniques based on several

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requirements which may not be feasible all the time. The comparison of various approaches is shown in Table 1.

Feature	Approach		
	Expert systems	**Artificial Neural Networks**	**Fuzzy Logic**
Knowledge used	Expert knowledge in the form of rules, objects, frames etc.,	Information extracted from the training set of cases	Expert knowledge in the form of protection criteria
Trouble shooting and improving a relay	Change of rules required	Difficult – the internal signals are almost impossible to interpret	Convenient – the internal signals are understandable and analyzable
Self-learning	Possible	Natural	Possible
Handling unclear cases	Possible	Natural	Possible
Robustness	Not critical and easy to ensure	Difficult to ensure	Not critical and easy to ensure
Setting a relay	Convenient	Large number of simulations required	Convenient both knowledge and simulation are required
Computations	Extensive	Dedicated hardware	Moderate

Table 1 Comparison of Various Approaches

VI. CONCLUSION

Artificial intelligence is an emerging field and the applications of AI in various fields of study only keeps growing day by day. Electrical engineering requires a lot of deliberation when it comes to manufacturing, maintenance and security and this is where artificial intelligence comes into the picture. Artificial intelligence has its fair share of advantages and disadvantages but the impact that the advantages have on electrical systems as a whole far outweighs the disadvantages. The different types of artificial intelligence available and the various applications of artificial intelligence in electrical engineering have been discussed in detail. It can also be concluded that artificial intelligence is an extremely viable choice of technology that can be included in the field of electrical engineering in order to not only make life simpler but also bring in a high degree of efficiency and reliability into the system. The several advanced, efficient and intelligent algorithms are widely developed to improve solutions accuracy to many real-world problems in diverse domains such as voltage and slope stability, power flow management, the estate of charge estimation, and rotor system diagnosis. This paper gives an overall idea about the advanced Artificial intelligence algorithms and techniques used to provide solutions to the power system challenges.

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