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Artificial intelligence: An advanced approach in power systems

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Abstract
A continuous and reliable supply of electricity is necessary for the functioning of today's modern and advanced society Power system has grown tremendously over a few decades. As per the demand is increasing respect to the time, the size and complexity of the power system also going to increase day by day which consists of generators, transmission lines, power transformers, distribution transformers etc. Due to the increments of the power systems it leads to the increase in the possibility of inviting huge no of faults. To ensure the need of people is fulfilled, detailed investigations and developments are in progress on power distribution systems and the monitoring of apparatus. The acquisition of data, the processing of those data for use by the operator, and control of remote devices are the fundamental building blocks of all modern utility control systems. Manual calculations, technical analysis and conclusions initially adopted the power system design, operation and control. As the power system grew it become more complex due to the technical advancements, variety and dynamic requirements. Artificial intelligence is the science of automating intelligent behaviours currently achievable by humans. Intelligent system techniques may be of great help in the implementation of area power system controls.

Keywords: artificial intelligence, expert system, artificial neural network, fuzzy logic, power station

Introduction

Power system engineering is an important branch of electrical engineering that deals with the generation, transmission, distribution, and utilisation of electric power. AI is the science of automating intelligent behaviours presently accomplishable by a computer interfaced with machines like robots. Artificial General Intelligence (AGI) is the intelligence of a hypothetical machine or computer which can accomplish any intellectual assignment successfully which a human being can accomplish. For industrial development with power system expansion; stability, strengthening, reliability, technical advancements, selection and dynamic response of the power system are essential. With the growth of the power system, complexity in the networks is increased tremendously. As a consequence of this power system analysis by conventional techniques and conclusions from the acquired data, the process for the information, management of remote devices and utility became more complicated and time-consuming. As necessity is the mother of invention, AI is developed with the help of sophisticated computer tools and applied to resolve all aforesaid problems for large power systems.

It is the science and engineering of making intelligent machine especially intelligent computer programs. One may expect that the mobile sensing will play an increasingly important role in the monitoring of power system. Commonly Artificial intelligence is known to be the intelligence exhibited by machines and software, for example, robots and computer programs. Colloquially, the term "artificial intelligence" is applied when a machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving". The term is generally used to the project of developing systems equipped with the intellectual processes features and characteristics of humans, like the ability to think, reason, find the meaning, generalize, distinguish, learn from past experience or rectify their mistakes.

Power Station

A power station, also referred to as a generating station, power plant, powerhouse, or generating plant, is an industrial facility for the generation of electric power. Most power stations contain one or more generators, a rotating machine that converts mechanical power into electrical power. The relative motion between a magnetic field and a conductor creates an electrical current. Most power stations in the world burn fossil fuels such as coal, oil, and natural gas to generate electricity. Others use nuclear power, but there is an increasing use of cleaner renewable-sources such: as solar, wind, wave and hydroelectric. An electric power system is a network of electrical components used to supply, transmit and use electric power.

There are three types of major power plants known for the massive electricity generation:

a. Thermal power plants.
b. Hydro power plants.
c. Nuclear power plants.

Thermal Power Plants

A thermal power station is a power plant in which heat energy is converted to electric power. In most of the places in the world the turbine is steam-driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankines cycle. Thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil-fuel power stations produce a large part of man-made CO2 emissions to the atmosphere, and efforts to reduce these are varied and wide spread.

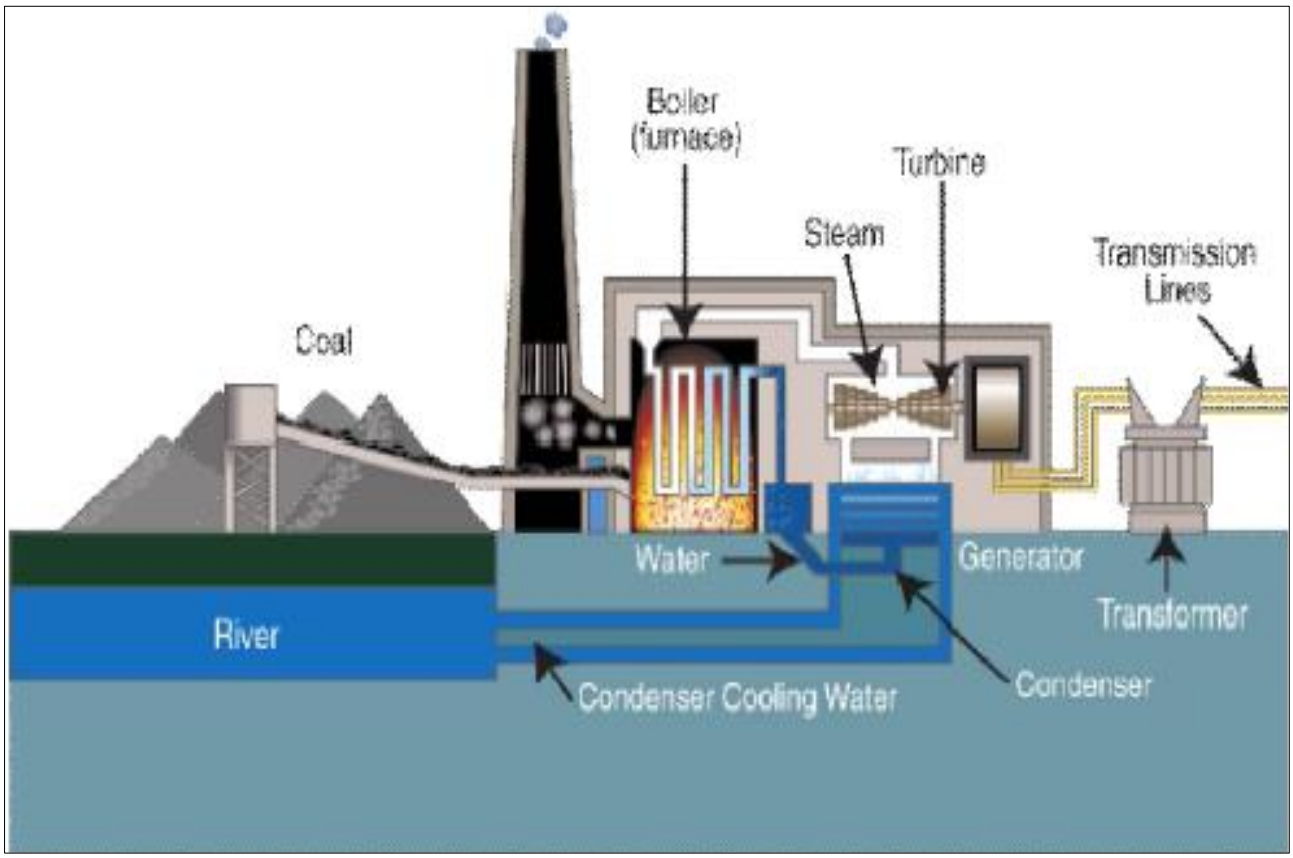

Fig 1: The above figure shows the layout of thermal power plant

Hydro Power Plant

Hydropower or waterpower is power derived from the energy of falling water or fast running water, which may be harnessed for useful purposes. In Hydro Power Plant we use gravitational force of fluid water to run the turbine which is coupled with electric generator to produce electricity. This power plant plays an important role in protecting our fossil fuel which is limited; because the electricity generated is due to the use of water which is a renewable source of energy. The force of the water being released from the reservoir through the dam spins the blades of a giant turbine. The turbine is connected to the generator that makes electricity as it spins. After passing through the turbine, the water flows back into the river on the other side of the dam.

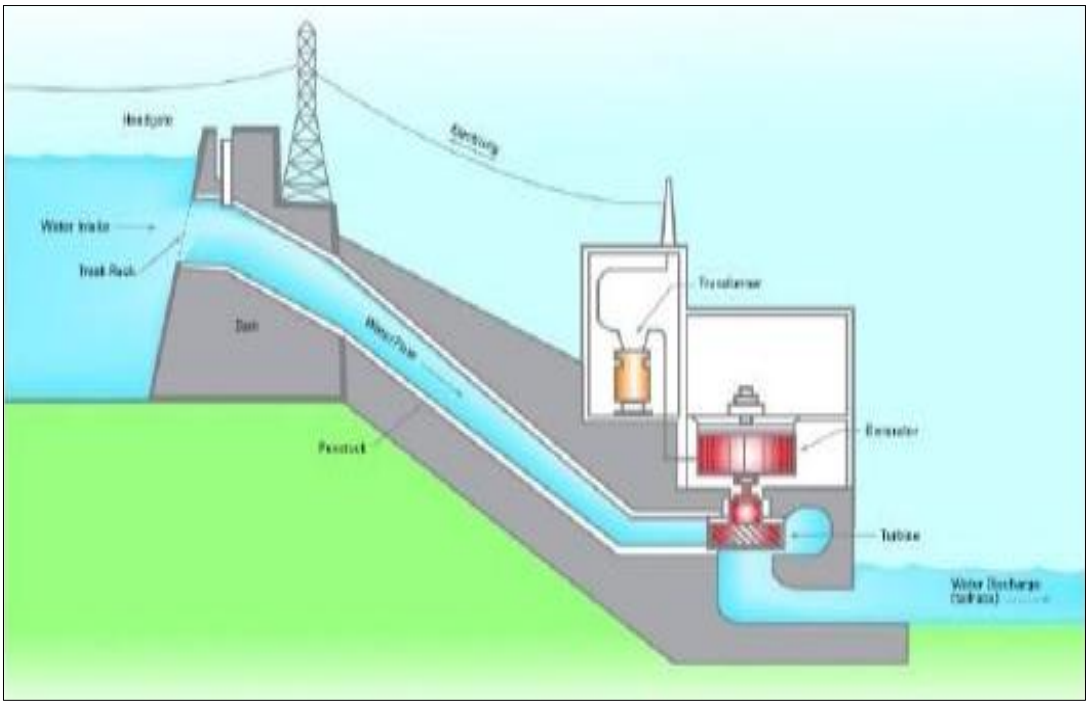

Fig 2: The figure shows the layout of hydro power plant structure

Nuclear Power Plant

A nuclear power plant is a thermal power station in which the heat source is a nuclear reactor. Nuclear plants, like plants that burn coal, oil and natural gas, produce electricity by boiling water into steam. This steam then turns turbines to produce electricity. The conversion to electrical energy takes place indirectly, as in conventional thermal power stations. The fission in a nuclear reactor heats the reactor coolant. The coolant may be water or gas or even liquid metal depending on the type of reactor. The reactor coolant then goes to a steam generator and heats water to produce steam. The pressurized steam is then usually fed to a multi-stage steam turbine. After the steam turbine has expanded and partially condensed the steam, the remaining vapour is condensed in a condenser.

The condenser is a heat exchanger which is connected to a secondary side such as a river or a cooling tower. The water is then pumped back into the steam generator and the cycle begins again. The water-steam cycle corresponds to the Rankine cycle.

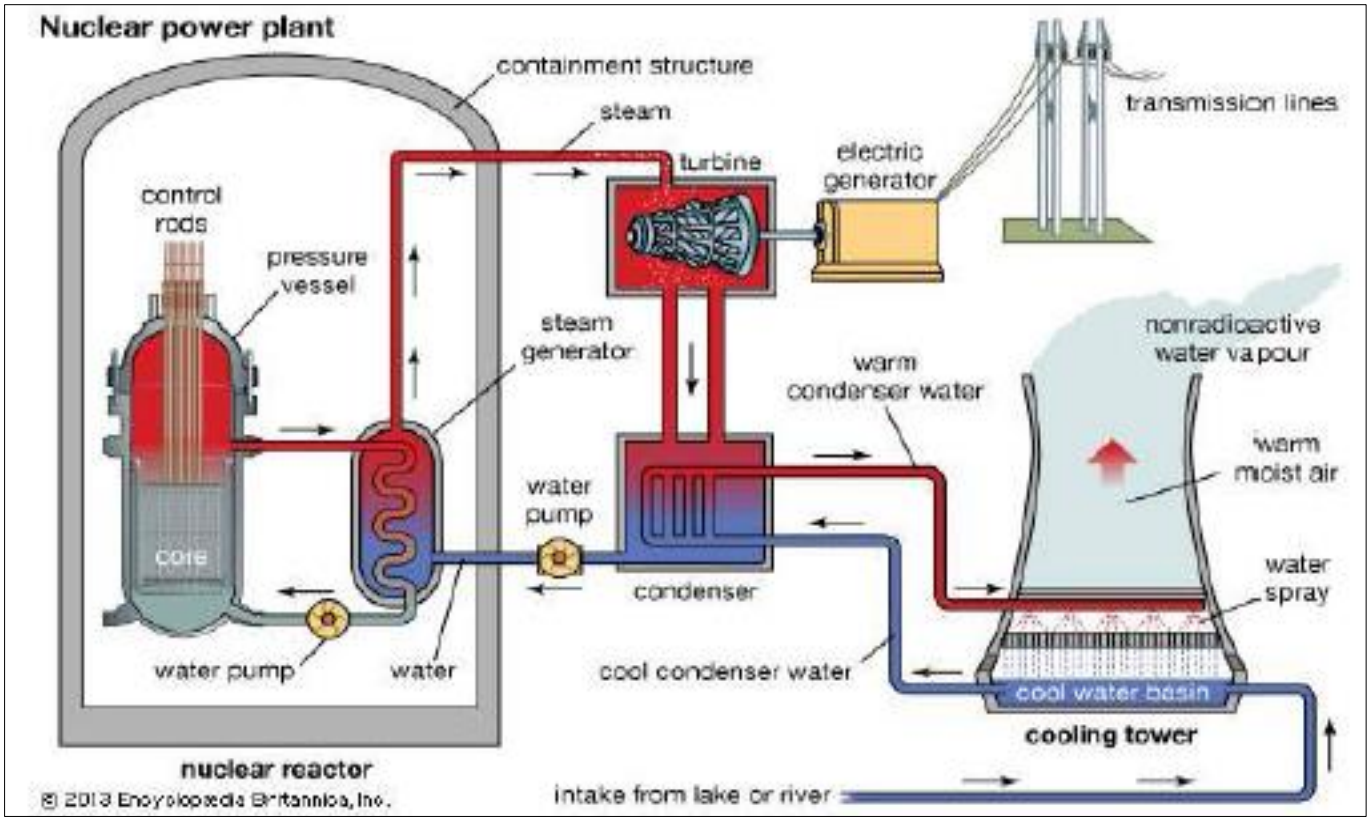

Fig 3: The figure shows the layout of nuclear power plant structure

Need of Ai In Power Stations

A. Increase in the computational time period and accuracy due to extensive and vast system data handling.
B. Complex, versatile and large amount of information which is used in calculation, diagnosis and learning.
C. Also used in the maintenance of the system.

AI Techniques implementation practical meaning

In the real world, the knowledge has some unwelcomed properties

A. Its volume is huge, next to unimaginable.
B. It is not well-organized or well-formatted.
C. It keeps changing constantly.

AI Technique is a manner to organize and use the knowledge efficiently in such a way that

A. It should be perceivable by the people who provide it.
B. It should be easily modifiable to correct errors.
C. It should be useful in many situations though it is incomplete or inaccurate.

AI techniques elevate the speed of execution of the complex program it is represented in fig 5.

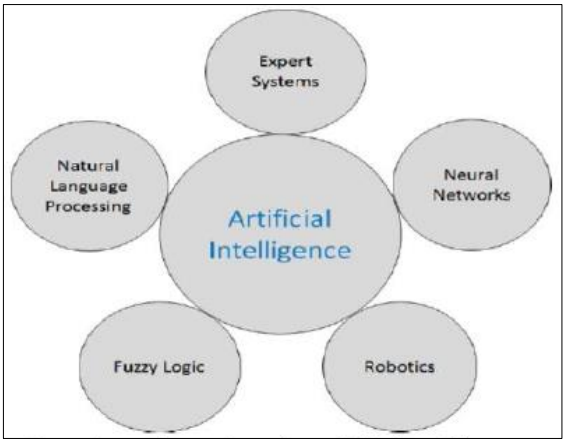

Fig 4: The above figure shows the main artificial intelligence techniques

Modern AI technologies include the following techniques:

- Artificial Neural Networks (ANNs)
- Expert System Techniques (XPS)
- Fuzzy Logic systems (FL)
- Genetic algorithm (GA)

These are the major families of AI techniques which are considered in the field of modern power system.

Artificial Neural Networks

Artificial Neural Networks (ANN) are biologically inspired systems. ANN mathematical models simulate the human biological neural network for processing information where each neuron produces one output as a function of inputs. Each type of neural network is capable of some specific work after being trained and is able to conclude a function from observations faced in real life such as function approximation, classification, data processing, etc. Its primary advantage is the capability to learn algorithms, an online adaption of dynamic systems, quick parallel computation, and intelligent interpolation of data. They are classified by their architecture, a number of layers, topology, connectivity pattern, feed forward, back propagation and radial basis function or recurrent, etc.

A neural network consists of some layers of artificial neurons linked by weight connections.

- **Input Layer:** The input units do not process the data and information but distribute other units.
- **Hidden Layer:** The hidden units provide the ability to map or classify the nonlinear problems.
- Output Layer: The output units encode possible values to be allocated to the case under consideration.

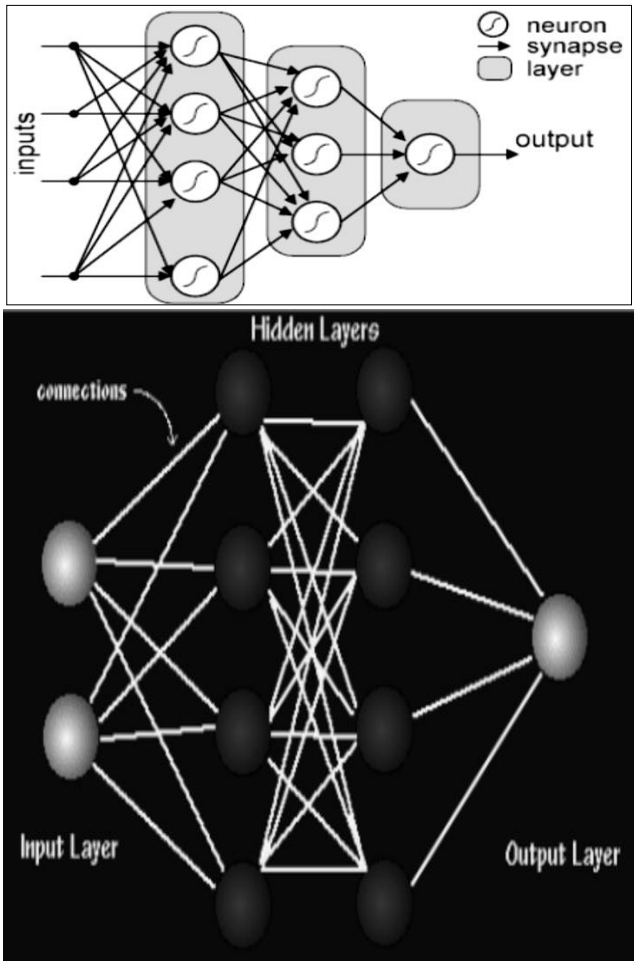

Fig 5: Architecture of a feed forward ANN

ANNs Characteristics

ANNs are fast and robust and do not need any appropriate knowledge of the system model. Since they are fault tolerant, they can handle situations of incomplete or corrupt data and information. They have learning and data adaptation ability. On the other hand, ANNs cannot perform a task other than the one for which they are trained. For any other task, they have to be retrained. ANNs always generate the result although the inputs data is unreasonable.

Applications

ANNs can be particularly useful for problems which require quick results, like those in real time operation. ANN techniques can be applied to power system protection.

Methodology

Real world problems in generation, transmission, and distribution of electricity can be fed to the ANNs to obtain a solution.

Fig 6

Expert System Techniques

In artificial intelligence, an expert system is a computer system that emulates the decision-making ability of a human expert

A. Expert systems are designed to solve complex problems by reasoning about knowledge, represented primarily as if–then rules rather than through conventional procedural code.
B. The first expert systems were created in the 1970s and then proliferated in the 1980s.
C. Expert systems were among the first truly successful forms of AI software.
D. An expert system is divided into two sub-systems: the inference engine and the knowledge base. The knowledge base represents facts and rules. The inference engine applies the rules to the known facts to deduce new facts. Inference engines can also include explanation and debugging capabilities.
E. These systems are used in real world applications wherein the need for classification of patterns and pattern recognition arises.

They are classified by their architecture
a. Number of layers and topology
b. Connectivity patterns
c. Feed forward or recurrent.

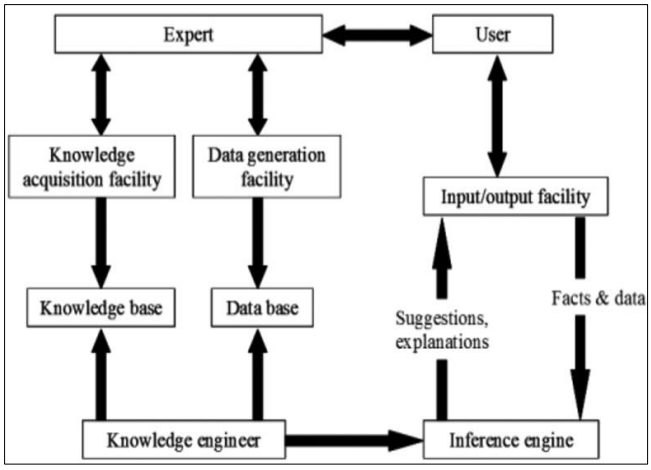

Fig 7

The components of ES include
1. Knowledge Base 2. Interface Engine 3. User-Interface

Expert systems in power station
Since expert systems are basically computer programs, the process of writing codes for these programs is simpler than actually calculating and estimating the value of parameters used in generation, transmission and distribution. Any modifications even after design can be easily done because they are computer programs. Virtually, estimation of these values can be done and further research for increasing the efficiency of the process can be also performed.

Advantages
A. Availability: Expert systems are available easily due to mass production software.
B. Cheaper: The cost of providing expertise is not expensive.
C. Reduced danger: They can be used in any risky environments where humans cannot work with.
D. Permanence: The knowledge will last long indefinitely.
E. Multiple expertise: It can be designed to have knowledge of many experts.
F. Explanation: They are capable of explaining in detail the reasoning that led to a conclusion. H. Fast response: They can respond at great speed due to the inherent advantages of computers over humans.
G. Unemotional and response at all times: Unlike humans, they do not get tense, fatigue or panic and work steadily during emergency situations.

Disadvantages
A. Large dimensionality.
B. Results are always generated even if the input data are unreasonable.
C. They are not scalable i.e. once an ANN is trained to do certain task, it is difficult to extend for other tasks without retraining the neural network.

Applications
A. All of the application solve offline tasks such as settings coordination, post fault analysis & fault diagnosis.
B. As yet there is no application reported of the expert system technique employed as a decision making tool in an on-line operating protective relay.

Fuzzy Logic
Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO. The conventional logic block that a computer can understand takes precise input and produces a definite output as TRUE or FALSE, which is equivalent to human's YES or NO.
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.

Fuzzy Logic Systems Architecture
It has four main parts as shown −
A. Fuzzification Module − It transforms the system inputs, which are crisp numbers, into fuzzy sets. It splits the input signal into five steps such as −

Table 1: The above table shows the fuzzification module

LP	x is Large Positive
MP	x is Medium Positive
S	x is Small
MN	x is Medium Negative
LN	x is Large Negative

B. Knowledge Base − It stores IF-THEN rules provided by experts.
C. Inference Engine − It simulates the human reasoning process by making fuzzy inference on the inputs and IFTHEN rules.
D. Defuzzification Module − It transforms the fuzzy set obtained by the inference engine into a crisp value.

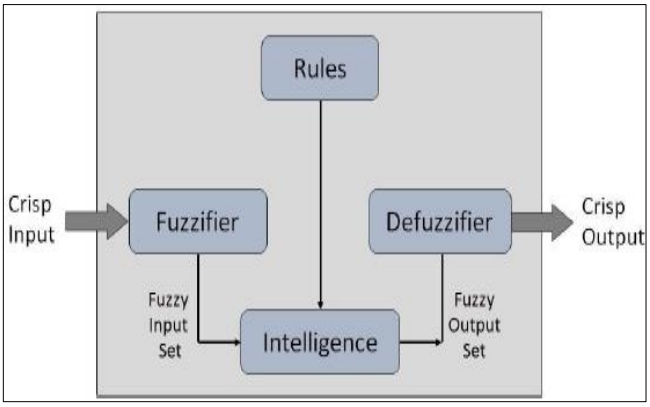

Fig 8: The above flowchart shows the Fuzzy Logic Controller

Fuzzy logic in power stations
Fuzzy logic can be used for designing the physical components of power systems. They can be used in
Anything from small circuits to large mainframes. They can be used to increase the efficiency of the components used in

power systems. As most of the data used in power system analysis are approximate values and assumptions, fuzzy logic can be of great use to derive a stable, exact and ambiguity-free output.

Advantages

A. Mathematical concepts within fuzzy reasoning are very simple.
B. You can modify a FLS by just adding or deleting rules due to flexibility of fuzzy logic.
C. Fuzzy logic Systems can take imprecise, distorted, noisy input information.
D. FLSs are easy to construct and understand.
E. Fuzzy logic is a solution to complex problems in all fields of life, including medicine, as it resembles human reasoning and decision making.

Disadvantages

A. There is no systematic approach to fuzzy system designing.
B. They are suitable for the problems which do not need high accuracy.

Applications

A. Fuzzy logic can be used in anything from small circuits to large mainframes.
B. They can be used to increase the efficiency of the components used in power systems.
C. Fuzzy logic can be used for designing the physical components of power systems.
D. As most of the data used in power system analysis are approximate values and assumptions, fuzzy logic can be of great use to derive a stable, exact and ambiguity-free output.

Implementation

A. It can be implemented in systems with various sizes and capabilities ranging from small micro-controllers to large, networked, workstation-based control systems.
B. It can be implemented in hardware, software, or a combination of both.
C. In order to process the input to get the output reasoning there are six steps involved in the creation of a rule
D. Identify the inputs and their ranges and name them.
E. Identify the outputs and their ranges and name them.
F. Create the degree of fuzzy membership function for each input and output.
G. Construct the rule base that the system will operate under
H. Decide how the action will be executed by assigning strengths to the rules
I. Combine the rules and defuzzify the output

Artificial Neural Networks

In machine learning and cognitive science, an artificial neural network (ANN) is a network inspired by biological Neural networks (the central nervous systems of animals, in particular the brain) which are used to estimate or approximate functions that can depend on a large number of inputs that are generally unknown. Artificial neural networks are typically specified using three things

Architecture

Specifies what variables are involved in the network and their topological relationships—for
Example the variables involved in a neural network might be the weights of the connections between the neurons,
Along with activities of the neurons

Activity Rule

Most neural network models have short time-scale dynamics: local rules define how the activities of the neurons change in response to each other. Typically the activity rule depends on the weights (the parameters) in the network.

Learning Rule

The learning rule specifies the way in which the neural network's weights change with time. This learning is usually viewed as taking place on a longer time scale than the time scale of the dynamics under the activity rule. Usually the learning rule will depend on the activities of the neurons. In an artificial neural network, simple artificial nodes, known as "neurons", "neurodes", "processing elements" or
"units", are connected together to form a network which mimics a biological neural network. There is no single formal definition of what an artificial neural network is. However, a class of statistical models may commonly be called “neural" if it possesses the following characteristics:

A. Contains sets of adaptive weights, i.e. numerical parameters that are tuned by a learning algorithm.
B. Is capable of approximating non-linear functions of their inputs.

Applications

A. Power System Stabilizer.
B. Load Forecasting.
C. Fault Diagnosis.
D. Security Assessment.
E. Voltage Stability Assessmen.t
F. Protection.

Genetic Algorithms (GA)

The Genetic algorithm gives a global technique based on biological metaphors. It is an optimisation technique based on the study of “Natural selection and natural Genetics.” Several methods for increasing the efficiency and analysis of power system to increase power output can be proposed, but out of these methods, Genetic Algorithms withstands all selected constraints.
It is the best method for solving complex and nonlinear problems. It is used for planning of power generation, transmission and distribution. It adjusts the parameters of excitation to solve the voltage control problem and reactive power compensation.

Current Application of Artificial Intelligence In Power Stations

There are lot of problems occurring daily in our power system which cannot be solved by conventional techniques are based on several requirements which may not feasible all the time. On that situation the artificial intelligence (AI) techniques are the main and only option.

Areas of application of AI in power systems are

A. Planning of power system like generation expansion planning, power system reliability, transmission expansion is planning, reactive power planning.
B. Control of power system like voltage control, stability control, power flow control, load frequency control.
C. Control of network like location, sizing and control of FACTS devices.
D. The understanding of the working of neurons and the pattern of their interconnection can be used to construct computers for solving real world problems of classification of patterns and pattern recognition.
E. Applications of distribution system like planning and operation of distribution system, demand side response and demand side management, operation and control of smart grids, network reconfiguration.
F. Can be used to increase the efficiency of the components used in power systems.
G. Forecasting application like short term and long term load forecasting, electricity market forecasting, solar power forecasting, wind power forecasting.
H. Some intelligent systems are capable of hearing and comprehending the language in terms of sentences and their meanings while a human talks to it. It can handle different accents, slang words, noise in the background, change in human's noise due to cold, etc.
I. This place a crucial role in strategic games such as chess, poker, tic-tac-toe, etc. where machine can think of large number of possible positions based on heuristic knowledge.

Conclusion

The field of artificial intelligence gives the ability to the machines to think analytically, using concepts. The main feature of power system design and planning is reliability, which was conventionally evaluated using deterministic methods. Moreover, conventional techniques don't fulfil the probabilistic essence of power systems. This
paper is based on the concept of artificial intelligence, areas of artificial intelligence and the artificial intelligence techniques used in the field of Power Systems A lot of research is yet to be performed to perceive full advantages of this upcoming technology for improving the efficiency of electricity market investment, distributed control and
Monitoring, efficient system analysis, particularly power systems which use renewable energy resources for operation.

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