

Exertion of Artificial Intelligence 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. Since the early to mid 1980s, most of the effort in power systems analysis has turned away from the methodology of formal mathematical modeling which came from the areas of operations research, control theory and numerical analysis to the less rigorous and less tedious techniques of artificial intelligence (AI). Power systems keep on increasing on the basis of geographical regions, assets additions, and introduction of new technologies in generation, transmission and distribution of electricity. AI techniques have become popular for solving different problems in power systems like control, planning, scheduling, forecast, etc. These techniques can deal with difficult tasks faced by applications in modern large power systems with even more interconnections installed to meet increasing load demand. The application of these techniques has been successful in many areas of power system engineering.

Keywords: Artificial intelligence, Power system engineering.

I. Introduction

ELECTRICAL POWER SYSTEMS

An electrical power system is a network comprised of electrical components that facilitate the supply, transmission, and utilization of electric power. Power systems engineering is a specialized field within electrical engineering that focuses on the generation, transmission, distribution, and utilization of electric power, as well as the devices connected to such systems, such as generators, motors, and transformers.

ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) refers to the intelligence exhibited by machines and software, such as robots and computer programs. It involves the development of systems that possess intellectual processes resembling those of humans, including abilities such as thinking, reasoning, understanding, generalizing, distinguishing, learning from past experiences, and correcting mistakes. Artificial general intelligence (AGI) pertains to the hypothetical intelligence of a machine or computer that can successfully perform any intellectual task that a human being can accomplish.

IMPORTANCE OF AI IN POWER SYSTEMS

The use of conventional techniques for power system analysis has become increasingly challenging due to the following factors:

1. The complexity, versatility, and vast amount of information involved in calculations, diagnostics, and learning.

2. The longer computational time and higher accuracy requirements resulting from the handling of extensive system data.

As energy consumption continues to rise and electrical transmission networks and lines expand, modern power systems operate close to their limits. This necessitates a less conservative approach to power system operation and control, which can only be achieved by continuously monitoring system states in great detail. Sophisticated computer tools, particularly Artificial Intelligence, have become instrumental in solving complex problems related to power system planning, operation, diagnostics, and design. AI has experienced significant advancements in recent years and has found extensive applications in the field.

I. Artificial Intelligence Techniques

1. ARTIFICIAL NEURAL NETWORKS (ANN)

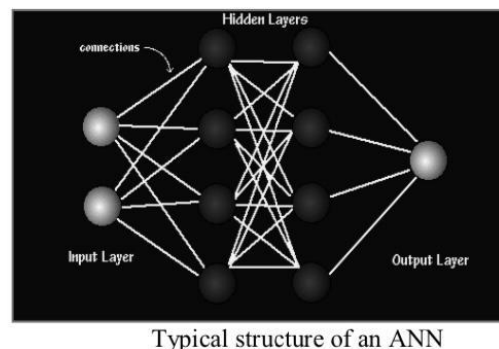
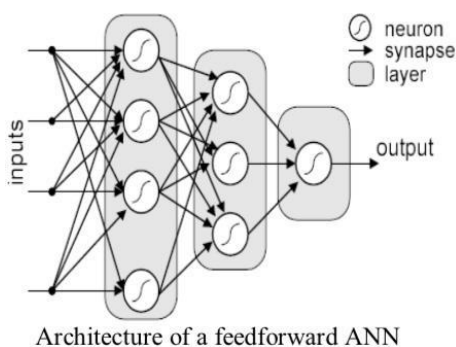
Artificial Neural Networks are computational systems that are inspired by the structure and functionality of biological neural networks. These networks consist of interconnected nodes called neurons, which receive inputs and produce outputs based on a non-linear operation. By understanding the behavior of neurons and their connections, we can develop computer models that excel at solving real-world tasks such as pattern classification and recognition.

The classification of neural networks is based on their architecture, which includes the number of layers and the topology, specifically the connectivity pattern and whether it is feedforward or recurrent.

In the input layer, the nodes serve as input units that do not process the data or information. Instead, their role is to distribute this data and information to other units within the network.

Hidden layers consist of nodes that are not directly observable or evident. These hidden units enable the networks to effectively map or classify nonlinear problems.

The output layer comprises nodes that act as output units. Their purpose is to encode possible values that can be assigned to the case being considered.



1.1. Advantages:

1. Rapid processing speed.
2. No need for extensive knowledge of the system model.
3. Ability to handle incomplete or corrupt data.
4. Fault tolerance.

5. ANNs are both fast and robust, with the capability to learn and adapt to data.
6. Generalization capability.

1.2. Disadvantages:

1. High dimensionality.
2. Results are generated even with unreasonable input data.
3. Lack of scalability, requiring retraining for new tasks.

1.3. Applications:

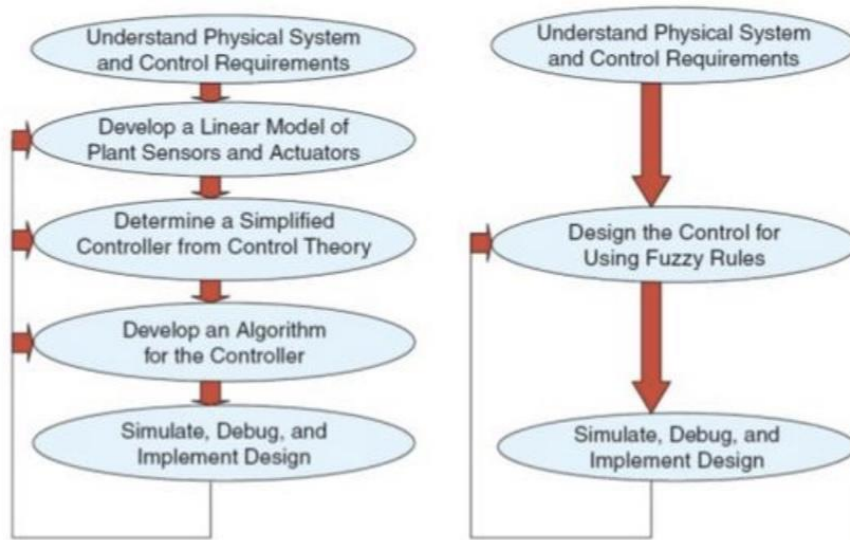
ANNs are suitable for power system problems involving encoding of nonlinear functions. They are particularly useful for time-sensitive problems, as they can quickly generate results based on input data.

1.4. Utilizing Artificial Neural Networks (ANNs) in power systems:

By leveraging the innate abilities of ANNs to mimic biological processes and analyze real-world issues, they can be effectively employed in addressing challenges related to electricity generation, transmission, and distribution. ANNs can be trained with the specific constraints of practical transmission and distribution systems, enabling them to accurately determine the precise values of parameters. For instance, ANNs can calculate the numerical values of inductance, capacitance, and resistance in a transmission line by considering various factors such as environmental conditions, unbalancing scenarios, and other potential issues. Furthermore, ANNs can also take the inputs of resistance, capacitance, and inductance values of a transmission line and generate a combined, normalized parameter value. This approach aids in mitigating skin effect and proximity effect to a certain degree.

2. Fuzzy Logic

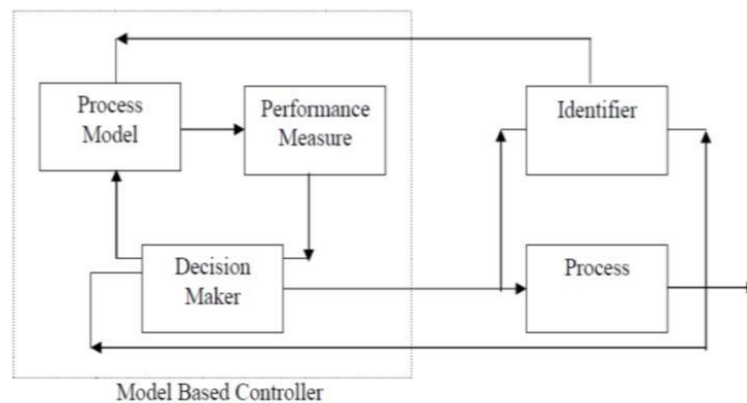
Fuzzy logic, also known as fuzzy systems, is a logical approach used to standardize and formalize approximate reasoning. It mimics human decision-making by effectively producing accurate solutions based on certain or even approximate data and information. The reasoning process in fuzzy logic closely resembles that of human thinking. By leveraging this technology, machines can perform tasks in a manner similar to humans, as it emulates the workings of the human brain. Fuzzification empowers fuzzy logic with enhanced expressive power, broader applicability, and the ability to model complex problems at a reasonable cost. Furthermore, fuzzy logic enables the incorporation of a specific level of ambiguity during analysis, as this ambiguity can effectively represent available information. Fuzzy logic proves to be beneficial in numerous applications as it helps to reduce problem complexity. In the context of power systems, fuzzy logic is particularly suitable for various areas where the information at hand is uncertain. For instance, a problem may require logical reasoning but can be applied to numerical inputs and outputs instead of symbolic ones. Fuzzy logic facilitates the conversion of numerical inputs into symbolic form and vice versa for the outputs.



Benefits of using fuzzy logic

2.1 Fuzzy Logic Controller

To put it simply, a fuzzy code is developed to govern various mechanisms, typically related to mechanical input. These controllers can exist either in software or hardware form and find applicability in a wide range of systems, spanning from compact circuits to extensive mainframes. By adapting to changing circumstances, adaptive fuzzy controllers acquire the ability to regulate intricate processes in a manner akin to human learning.



2.2. Applications:

1. Stability analysis and improvement
2. Regulation of power system
3. Identification of faults
4. Evaluation of security
5. Prediction of load
6. Planning and control of reactive power
7. Estimation of system state

2.3. Reactive Power and Voltage Control

The primary types of voltage issues are as follows:

1. Determining the reactive power requirements and control mechanisms for the system.
2. Implementing resources for reactive power control.
3. Operating the existing voltage resources and control devices.

To enhance the voltage profile of the power system through reactive power control, fuzzy logic has been utilized. The voltage deviation and control variables are transformed into fuzzy set or fuzzy system notations to establish the relationship between voltage deviation and the control capability of the control device. The key control variables include generator excitation, transformer taps, and VAR compensators. A fuzzy system is developed to select these control variables and determine their adjustments.

2.4. How fuzzy logic can be used in power systems:

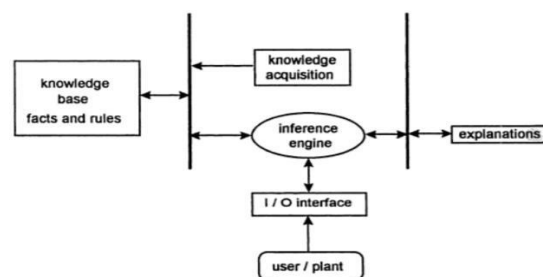
The control variables are chosen based on two criteria: local controllability towards a bus with unacceptable voltage and overall controllability towards buses with poor voltage profiles.

Fuzzy logic can be applied in power systems to design the physical components, ranging from small circuits to large mainframes. It can enhance the efficiency of these components by utilizing approximate values and assumptions commonly used in power system analysis. By employing fuzzy logic, a stable, precise, and unambiguous output can be derived.

Expert systems are computer programs that capture the knowledge of human experts in a specific domain and convert it into a format that can be implemented by machines. These systems possess expertise and proficiency in a particular field. The knowledge is typically stored separately from the procedural part of the program and can be represented in various forms such as rules, decision trees, models, and frames. Expert systems are also known as knowledge-based systems or rule-based systems. They utilize the interface mechanism and knowledge to solve problems that may be challenging or impossible for human skill and intellect.

3. Expert System

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Structure of an Expert System

3.1. Benefits:

1. It offers permanence and consistency.
2. It can be conveniently recorded.
3. It can be easily shared or replicated.

3.2. Drawback:

Expert Systems lack the ability to acquire knowledge or adapt to new problems or situations.

3.3. Implementations:

Expert systems find extensive applications in power systems, where they excel in decision-making, knowledge preservation, and problem-solving through reasoning, heuristics, and judgment. They prove particularly valuable when there is a need to process a large volume of data and information within a limited timeframe.

3.4. Utilizing expert systems in power systems:

Expert systems, being computer programs, offer a simpler approach to writing code compared to the complex calculations and estimation of parameters involved in power generation, transmission, and distribution. The advantage of these systems lies in their flexibility, as modifications can be easily made even after the initial design phase due to their nature as computer programs. Additionally, expert systems enable the estimation of values and further research can be conducted to enhance the efficiency of the overall process.

4. GENETIC ALGORITHMS (GA)

Genetic algorithms (GA) are optimization techniques that draw inspiration from the principles of natural selection and genetics. The fundamental concept behind GA is that the most fit individual within a population has the highest likelihood of survival. By employing biological metaphors, GA provides a global approach to optimization. What sets genetic algorithms apart from other optimization methods are two key factors:

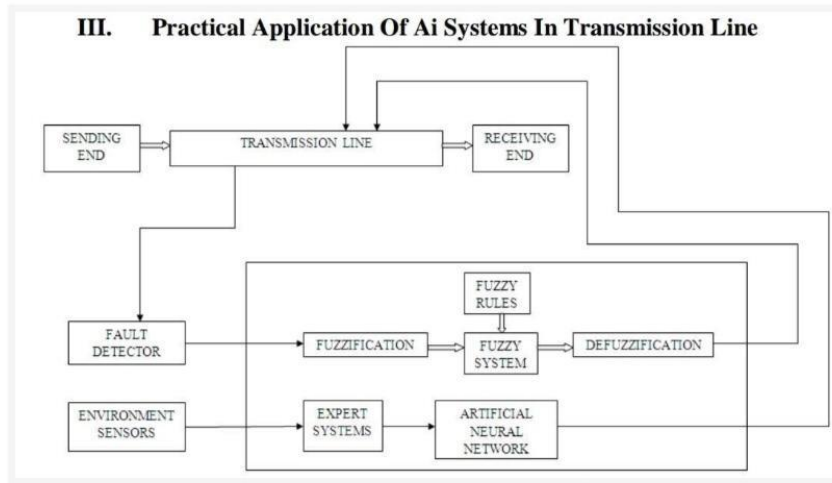
1. Instead of working directly with the actual variables, genetic algorithms operate on the coding of the variables set.
2. Genetic algorithms search for optimal points by exploring a population of potential solution points, rather than focusing on a single point.
3. The genetic algorithm relies exclusively on the information provided by the objective function.
4. The genetic algorithm functions based on probability transition laws rather than deterministic laws.
5. The GA utilizes predefined parameter values.

Applications:

Genetic algorithms have a wide range of applications in power systems, encompassing various areas such as planning, operation, and analysis. In terms of planning, genetic algorithms can be utilized for tasks like determining the optimal positioning of wind turbines, optimizing reactive power, routing network feeders, and placing capacitors. When it comes to operation, genetic algorithms can aid in coordinating hydro-thermal plants, scheduling maintenance, minimizing losses, managing loads, and controlling FACTS (Flexible AC Transmission Systems). Additionally, in the realm of analysis, genetic algorithms can

address issues like reducing harmonic distortion, designing filters, controlling load frequency, and analyzing load flow.

Utilizing genetic algorithms in power systems can significantly enhance efficiency and increase power output. By employing genetic algorithms, it becomes possible to identify the most suitable method that satisfies all constraints, thereby determining the optimal solution based on the principle of survival of the fittest.



Consider a practical transmission line. In the case of a fault occurrence, the fault detector will detect the fault and transmit the information to the fuzzy system. This method only necessitates the implementation of three line currents, and the angular difference between the fault and pre-fault current phasors is utilized as input for the fuzzy system. Subsequently, the fuzzy system produces a clear output that indicates the type of fault. The utilization of fuzzy systems can generally enhance fault diagnosis.

To improve the performance of the transmission line, Artificial Neural Networks (ANNs) and Expert systems can be employed. Environmental sensors are responsible for detecting and measuring the environmental and atmospheric conditions, which are then provided as input to the expert systems. These expert systems are computer programs developed by knowledge engineers, and they generate the appropriate values for the line parameters as output. The ANNs are trained to adjust the values of the line parameters within specified ranges based on the environmental conditions. A training algorithm is necessary for the ANN. Once the training is completed, the neural network is tested, and the performance of the updated trained neural network is evaluated. If the performance does not meet the desired level, adjustments can be made, such as altering the number of hidden layers or the number of neurons in each layer. The processing speed of the system is directly affected by the number of neurons.

Feature	Approach		
	XPS	ANNs	FL
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.	Natural.
Robustness	Not-critical and easy to ensure.	Difficult to ensure.	Not-critical and easy to ensure.
Setting a relay	Convenient.	Large number of simulation required.	Convenient. Both knowledge and simulation are used.
Computations	Extensive.	Dedicated hardware.	Moderate.

Current Application of Artificial Intelligence in Power Systems

Artificial intelligence (AI) techniques have become essential in addressing various challenges encountered by power systems that cannot be effectively resolved using traditional methods. The utilization of AI in power systems encompasses several application areas:

1. **Operation of power systems:** AI is employed in tasks such as unit commitment, hydro-thermal coordination, economic dispatch, congestion management, maintenance scheduling, state estimation, load, and power flow.
2. **Planning of power systems:** AI plays a critical role in generation expansion planning, power system reliability, transmission expansion planning, and reactive power planning.
3. **Control of power systems:** AI techniques are utilized in voltage control, stability control, power flow control, and load frequency control.
4. **Control of power plants:** AI is applied in the control of fuel cell power plants and thermal power plants.
5. **Control of networks:** AI techniques are employed in the location, sizing, and control of FACTS (Flexible AC Transmission Systems) devices.
6. **Electricity markets:** AI is utilized in the development of strategies for bidding and analyzing electricity markets.
7. **Automation of power systems:** AI is employed in tasks such as restoration, management, fault diagnosis, and network security.
8. **Applications in distribution systems:** AI techniques are used in the planning and operation of distribution systems, demand-side response and management, operation and control of smart grids, and network reconfiguration.
9. **Applications of distributed generation:** AI plays a role in distributed generation planning, control of solar photovoltaic power plants, control of wind turbine plants, and utilization of renewable energy resources.
10. **Forecasting applications:** AI techniques are employed in short-term and long-term load forecasting, electricity market forecasting, solar power forecasting, and wind power forecasting.

In conclusion, the integration of AI in power system design and planning has revolutionized the field by providing more reliable solutions.

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