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A Review on Applications of Artificial Intelligence Technologies In Power Systems

Seepana Jyotshna[1], N.Hema Tulasi Reddy[2]

[1,2] Department of Electrical and Electronics Engineering GMR Institute of Technology

Abstract: The running of today's contemporary and advanced society requires a consistent and steady source of electricity. Since about the early 1980s, the most of the effort in power systems study has shifted away from the paradigm of formal mathematical analysis, which originated in the fields of operations research and statistics. Control theory of less rigorous and less time-consuming methodologies of artificial intelligence which are artificial neural network, expert systems, fuzzy logic and genetic algorithm. Power systems continue to expand as a result of geographical regions, asset acquisitions, and introduction of new technologies in electricity generation, transmission, and distribution. AI approaches have advanced used for handling various problems in power systems such as control, scheduling, planning, forecasting, and so on. Artificial Intelligence in the System Operation Control and transient systems, its various methodologies and artificial intelligence techniques in power system protection were also discussed

Index terms: *Power systems, artificial intelligence, artificial neural network, fuzzy logic, expert system, genetic algorithm, power system protection.*

Introduction:

POWER SYSTEMS:

A network of electrical devices used to supply, transmit, and utilize electric power makes up an electric power system. Electrical engineering's subspecialty known as "power systems engineering" deals with the production, delivery, and use of electric power as well as the electrical equipment connected to it. such devices as transformers, motors, and generators.

ARTIFICIAL INTELLIGENCE (AI):

The theory and development of computer systems are able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.

There are three types of artificial intelligence

- ARTIFICIAL NARROW INTELLIGENCE
- ARTIFICIAL GENERAL INTELLIGENCE
- ARTIFICIAL SUPER INTELLIGENCE

TABLE: TYPES OF ARTIFICIAL INTELLIGENCE

ARTIFICIAL NARROW INTELLIGENCE (ANI)	ARTIFICIAL GENERAL INTELLIGENCE (AGI)	ARTIFICIAL SUPER INTELLIGENCE (ASI)
Stage-1 Machine Learning	Stage-2 Machine Intelligence	Stage-3 Machine consciousness

DEMAND FOR AI IN POWER SYSTEMS:

The electricity is transmitted and supplied to all machines utilizing power systems. Artificial intelligence (AI) is used to tackle a wide range of issues in power systems, involving scheduling, calculating, statistics, as well as predicting.

AI techniques are gaining popular for overcoming a variety of issues in power systems, including control, planning, scheduling, and forecasting.

Power Systems using AI Traditional methods for power system analysis become more challenging as a consequence of:

(1) Complex, versatile and enormous amounts of data, which is employed in calculation, diagnosis and learning.

(2) Increase within the computational period of time and accuracy thanks to extensive

Feasibility of the application of AI for a variety of topics in power systems has been explored by a number of investigators. Topics explored vary from load forecast to real-time control and protection, and even maintenance. Vast system data handling.

Because of the ever-increasing energy consumption, the modern power system is stretched to its limits as well as the expansion of existing electrical transmission networks and lines This situation necessitates a less formal approach. primary tools for resolving difficult problems in power system planning, operation, and maintenance, design and diagnosis among these computer tools, Artificial Intelligence has risen to prominence in recent years.

ADVANTAGES AND DISADVANTAGES OF ARTIFICIAL INTELLIGENCE:

ADVANTAGES:

(1) AI techniques are permanent and consistent.
(2) Speed of processing is good.
(3) Easy to document and reproduce.
(4) They are fast and robust.
(5) They are fault tolerant.

DISADVANTAGES:

(1) AI techniques are unable to adapt for new situations.
(2) They have large dimensionality.
(3) They are not scalable.

TOP AI APPLICATIONS:

- Healthcare
- E-commerce
- Robotics
- Finance
- Facial recognition
- Marketing
- Social Media

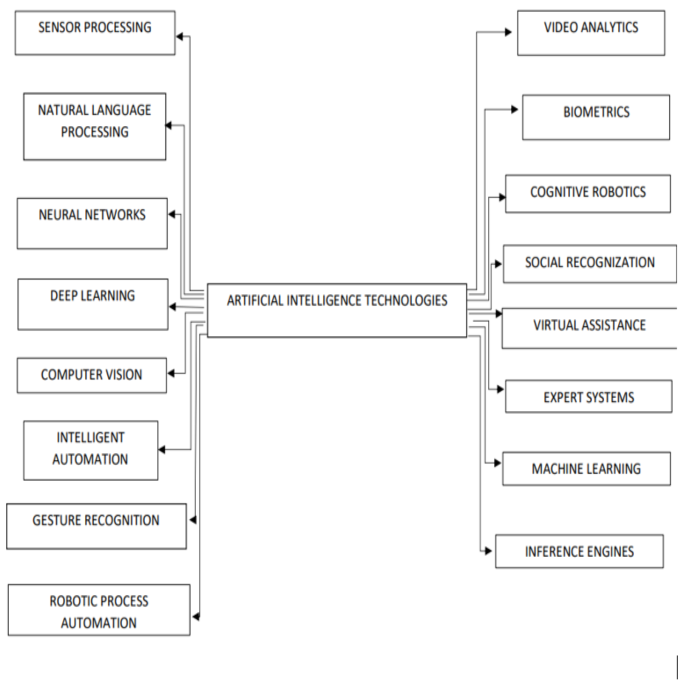

FIGURE: Applications of artificial intelligence.

MODERN ARTIFICIAL INTELLIGENCE TECHNOLOGIES

(1) The artificial neural network.

(2) The theory of fuzzy recognition and diagnosis.
(3) Expert system.
(4) Genetic algorithm.

ARTIFICIAL NEURAL NETWORK:
The Artificial neural network is from the perspective of simulated neurons process information using nonlinear mapping method of brain information processing, storage and search mechanism and combining it with AI mechanism.

ADVANTAGES OF ANN:
- Alter to known conditions.
- It is powerful and ease of use.
- It can model difficult situations.
- It can be imposed in any of the applications.

DISADVANTAGES OF ANN:
- The neural network needs the training to be operated.
- At times it forgets and also not exact.
- Large complexity of network structure.

APPLICATIONS OF ANN FOR POWER PLANTS:
- Identification and modelling
- Control
- Sensor validation
- Monitoring and fault diagnosis

IDENTIFICATION AND MODELLING:
An ANN is used to anticipate one or more of the sensor outputs. If there is a significant difference between the expected and obtained outputs, the instrumentation, system, or component has changed. The topics include transient diagnostics, sensor validation, plant-wide monitoring, check valve monitoring, and vibration analysis. This is an intriguing way for sensor function validation and early defect detection. The majority of the works indicated have been accomplished to demonstrate the feasibility of an ANN method.

CONTROL:
The neural network outputs were the desired parameters of the power system stabilisers. The generator's real power and power factor were utilized as inputs. Both are measured in real time and are indicative of the operational circumstances. The usefulness of this strategy was proved by simulation results. We employed multilayer feedforward neural networks. Because it does not require model identification, this technique is more efficient than self-tuning controllers and hence better suited for real-time applications.

SENSOR VALIDATION:
It was demonstrated that an ANN can be used to validate the precision of process variable measurements. Several process variables are measured, linked to the target process variable, and fed into the approach's ANN. The ANN output is an estimation of the target process variable. The actual value is compared to this estimate. The agreement decides whether or not the target instrument is operational. Flowmeters in the two feed water flow loops were evaluated in the TMI-1 nuclear power plant application. We used backpropagation and multilayer feedforward techniques. According to the simulation results, the target variable had precise measurements. The robustness of the system is investigated.

MONITORING AND FAULT DAIGNOSIS:
A model-reference technique was used to

develop a fuzzy expert system for monitoring nuclear reactor systems. The expert system performs basic interpretation and identification functions. The model is provided by ANNs, which identify general categories of system behavior and generate membership functions. These membership functions can be used as fuzzy controller inputs without the need to fuzzify the measured input values. The system enables monitoring of equipment operation and estimation of process variable values (virtual measuring). It was reported that the system was extremely resistant to loud and defective transmissions. The system description is appropriate for control applications.

APPLICATIONS OF ANN IN POWER SYSTEMS:

- Static and dynamic security assessment.
- Transient stability assessment.
- Identification, modelling and prediction.
- Control.
- Load forecasting.
- Fault diagnosis

STATIC AND DYNAMIC SECURITY ASSESSMENT:

A significant contribution to the employment of Artificial Neural Networks (ANN) in electric power systems. This paper, which was cited by the majority of the authors in ANNs and power systems, dealt with dynamic security assessment. To compute the Critical Clearing Time, an adaptive pattern recognition approach based on a Rumelhart feedforward neural net with a backpropagation learning algorithm was used (CCT). This value is critical in the post-fault dynamic study of interconnected systems. The net completed the estimation task for the variable system topology conditions successfully. This work prompted the investigation (mentioned in the following paragraph) of a pre-processing step capable of "discovering" which features were significant to the learning task and which were not.

TRANSIENT STABILITY ASSESSMENT:

A frequency domain pattern recognition methodology (primary result) for assessing the transient stability of an interconnected power system. We employed a decision-making system (DMS) with a pre-processor (parallel computing framework) and two layers of equivalent neurons. The primary distinction between DMS and multilayer ANN is that DMS requires a perceptron convergence technique rather than a backpropagation learning strategy. To determine transient stability, the DMS employs telemetered observations of electromechanical oscillations.

An ANN-based approach for detecting voltage instability. A hybrid ANN was used: a multilayer perceptron was used to estimate voltage instability indices, and a Kohonen self-organization mapping was used to trace power system condition trajectories. Network configuration changes were taken into account. A decentralized technique for monitoring voltage stability in real - world systems was also provided.

IDENTIFICATION, MODELLING AND PREDICTION:

The use of an ANN in conjunction with state estimation to monitor harmonic sources in a power system with nonlinear loads is investigated. Estimates generated

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by the ANN are used as pseudo measurements for harmonic state estimation. Simulation studies revealed that this method yields good results. We employed a feedforward ANN and backward error propagation.

The dynamic load modelling problem The authors compared and analyzed two models: a multi-layer feedforward ANN utilizing backpropagation learning and a standard difference equation (DE) technique employing recursive extended least square identification. Chinese Power Systems measured data was used. The results demonstrated that utilizing the measurement-based dynamic load modelling method, ANN can accurately depict the voltage-power nonlinear relationship. DE, however, cannot. More research on the interpolation and extrapolation of ANN models was suggested.

CONTROL:

An ANN approach to efficient capacitor regulation in distribution networks. The specific case was to manage the multi-tap capacitors installed in a distribution system for a nonconforming load profile in order to minimize system losses. A computationally efficient technique based on an expert system and two-stage ANN was used in the development. The control net was divided into two parts: one to anticipate the load profile and the other to select the best capacitor. As a pattern recognizer, an ANN was used, and an expert system was used as an inference engine. The outcomes were satisfactory. When compared to an optimization method, far less calculation time was required. This approach is appropriate for implementing on-line control even in big distribution systems.

LOAD FORECASTING:

The ANN's potential in electric load forecasting. One-hour and one-day intervals were considered. The results of simulations revealed that the proposed approach had lower average error than standard strategies. A multilayer perceptron is what the ANN is. Weather (temperature) and load data were used. The programme makes no assumptions about the functional link between load and weather. Because of the changes in load profiles, the authors also tested with one ANN for days with comparable load profiles and another ANN for each day with a distinct load profile, with good results.

FAULT DAIGNOSIS:

ANN is used to detect potential defects in power distribution feeders. Specifically, the potentials of the ANN technique in the identification of High-Impedance Faults are demonstrated (HIF). Feedforward neural networks and backpropagation learning methods were used. In most situations, the simulation findings indicated agreement. The net appeared to have trouble discriminating between two high frequency activities: capacitor switching and HIF. Actual field data will be required for more effective evaluation. The method demonstrated considerable promise as well as a more effective way for detecting HIF. This work was deemed extremely theoretical and would necessitate additional research.

THE THEORY OF FUZZY RECOGNITION AND DIAGNOSIS:

FUZZY LOGIC: Fuzzy theory by definition is fuzzy concepts and mathematical models for handling the practical concept is not clear or obscure facts such as: excessive current, too much loss in which membership does not clear.

Fuzzy logic is the logical concept of standardization and formalization of appropriate reasoning. It is a kind of human decision making with a capacity to find the accurate and exact solutions from certain or even proper information.

ADVANTAGES:

- Fuzzy logic is based on linguist model and is similar to human reasoning.
- Rapid operation can be done and high precision.
- It can be able to manage with improper data.

DISADVANTAGES:

- It has restricted number of usage of input variables.
- Not works for programs that are much larger or smaller than the historical data.
- It has lower speed and also longer run time of system.

FUZZY SYSTEMS:

The binary logic of expert systems describes and manipulates exact concepts; fuzzy systems theory allows uncertainties in problem formulation to be expressed and processed. Applications in which fuzzy concepts are used include fuzzy regression models, statistical decision making using fuzzy probability and fuzzy entropy, fuzzy quantification theory, fuzzy mathematical programming especially fuzzy linear programming, evaluation using fuzzy measures, diagnosis using fuzzy relations, fuzzy control and inference, multistage decisions using fuzzy dynamic programming, fuzzy databases and information retrieval using fuzzy functions and fuzzy expert systems. Although a considerable industry has grown up in the mathematical underpinnings of fuzzy, the basic ideas of fuzzy logic may be readily appreciated. The concepts of low, normal and high voltage are imprecise and subjective-nevertheless they offer a way of representing value judgments which can be expressed with degrees of certainty.

FUZZY REASONING:

Fuzzy logic is based on the rules of the form "IF .... THEN....... 'I that convert an input fuzzy set to an output fuzzy set. The input fuzzy sets of temperature have been mapped into output fuzzy sets of power demand by fuzzy rules. In effect the interaction of the input and output sets form a fuzzy patch covering part of the graph of the unknown function describing the relationship between temperature and power. Each fuzzy rule defines a fuzzy patch in the product space (Temperature*Power Demand). The fewer the patches the greater the degree of approximation, the more patches the greater the number of rules and the longer the computation time required for evaluation.

APPLICATIONS OF FUZZY LOGIC:

- Stability analysis and enhancement.
- Power system control.
- Fault diagnosis.
- Security assessment.
- Load forecasting.

- Reactive power planning and its control.
- State estimation.

EXPERT SYSTEMS

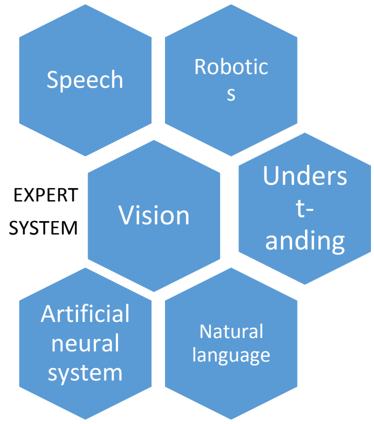
INTRODUCTION TO EXPERT SYSTEMS:

Expert system is a kind of intelligent computer software system which is built by human experts. It contains a 3large amount of professional knowledge and rich experience in the power system. Its use has penetrated into all fields. Especially in the field of artificial intelligence technology and even exceed the level of human expert.

An expert system converts the knowledge of a human expert in a specific topic into a machine-readable format. Expert systems are computer programs which have proficiency and competence in a particular field.

- An Expert System (ES) is a computer program that assimilates and reasons with knowledge obtained from some expert(s) with a view to solving problem(s) or giving advice.
- An Expert System is a computer system that emulates the decision making ability of a human expert.
- Expert Systems are designed to solve complex problems by reasoning about knowledge, like an expert.
- Expert systems are software packages which translate human expertise into computer programs.
- Among the artificial intelligence techniques, expert or knowledge based systems have been the most successful.

- The applications include Alarm Processing, System Diagnosis, Faults and Protection.



INTEGRATION OF AI IN EMS:

It is known that the integration of AI in energy systems will deliver a wide range of potential research opportunities to the energy management community. Innovative Artificial Intelligence solutions can enhance the efficiency, stability, robustness, and security of energy systems.

MASSIVELY PARALLEL AI:

Massively Parallel Artificial Intelligence is a new and growing area of AI research, enabled by the emergence of massively parallel machines. It is a new paradigm in AI research. A high degree of parallelism not only affects computing performance, but also triggers drastic change in the approach toward building intelligent systems; memory-based reasoning and parallel marker-passing are examples of new and redefined approaches.

The importance of massively parallel artificial intelligence has been recognized in recent years due to three major reasons:

1. increasing availability of massively parallel machines,
2. increasing interest in memory-based

reasoning and other highly-parallel AI approaches.

3. development efforts on Very Large Knowledge Bases (VLKB).

DATA MINING:

Data mining algorithms are extensions of machine learning algorithms. Data mining is defined as the nontrivial extraction of implicit, the previously unknown, and potentially useful information from data.

The main differences between data mining and machine learning are:

1. Data mining is concerned with finding understandable knowledge, while machine learning is concerned with improving the performance of a learning agent.

2. Data mining is concerned with very large, real-world databases, while machine learning typically (but not always) looks at smaller data sets. So efficient learning questions are much more important for data mining

3. Machine learning is a broader field which includes not only learning from examples, but also reinforcement learning, learning with teacher, learning by analogy, etc.

Therefore, data mining is that part of machine learning which is concerned with finding understandable knowledge in large sets of real-world example.

EXPERT DATABASE:

Expert database systems (EDS) are database management systems (DBMS) endowed with knowledge and expertise to support knowledge-based applications which access large shared databases.

CASUAL BASED OR MODEL BASED:

AI modelling is the creation, training, and deployment of machine learning algorithms that emulate logical decision-making based on available data. AI models provide a foundation to support advanced intelligence methodologies such as real-time analytics, predictive analytics, and augmented analytics

ADVANTAGES

- Increased output and also productivity.
- Easier equipment operation and also economical equipment cost.
- Reduces training costs for employees.
- It gives undeviating answer for repetitive decisions, processes and tasks.
- It can be easily documented, transferred or replaced.

DISADVANTAGES:

- In some decision making situations, it lacks human common sense.
- Lack of flexibility and capacity to adapt to changing environments.
- The computer reasoning is only good up to the rules it was given with.
- It is very expensive to set up in the initial place.
- Errors may occur in the knowledge base.

HOW EXPERT SYSTEMS CAN BE APPLICABLE IN POWER SYSTEMS:

Expert systems can always be used in power systems as follows: Because expert systems are essentially computer programs, writing the codes for these programs is straightforward and less difficult than calculating and predicting the values of parameters used in generation, transmission, and distribution. Because they are computer programs, they can be changed even after they have been designed. These values can be estimated effectively, and further research to improve process reliability can also be carried out.

GENETIC ALGORITHM

PRINCIPLES OF GA:

GENETIC ALGORITHM: Genetic algorithm replicate of the computer model of evolutionary in biology to natural selection and genetic mechanism. The aim is to find the optimal solution in the large search space, which can be adapted to the transformation between the individual units and the control strategy of the search group.

- In principle the structure of a genetic algorithm is fairly simple The process can be illustrated by reference to a popular application area, that of optimal power flow. The data supplied for AC load flow studies will comprise, apart from the network parameters and connections and loads, information regarding generator maximum and minimum active and reactive power outputs and transformer variable tap ranges. The choice of values within these ranges has to be made to subject to a number of constraints such as minimize an objective function, (usually generation cost), network laws, plant loading limits, bus-bar voltage limits, line loading constraints, area power flow interchange constraints, security constraints, etc.
- A load flow program will model the network, thus taking care of the network laws. Given any specified combination of generator output power and bus-bar voltage magnitudes together with transformer tap settings the load flow can check the system constraints and the generation cost found. Within this framework genetic algorithm's model a solution by means of binary strings. Such a string is made up of sub-strings, each sub-string representing a different variable, say P5, the output power of generator 5. If a sub-string has a 4-bit length, e.g., then it would allow a representation of sixteen different values of Ps. In the terminology of genetic algorithm. The bits are referred to as "genes" and the total string a "chromosome". A chromosome, therefore, represents a solution; several chromosomes representing different solutions comprise a "population".

ADVANTAGES

- The algorithm is very easy to write.
- It can easing determine the mistakes done by non-computer systems.
- It can optimize large number of constants and is very good at optimizing.
- It is more efficient and faster than the traditional methods.

DISADVANTAGES:

- It is a time taking process.
- It is hard to show branching and looping.
- It cannot handle big tasks to be written into algorithm.

APPLICATIONS OF GA:

- Designing electrical circuits such as antenna design.
- Multiple criteria production scheduling.
- Designing of aircrafts.

- Also applicable to robot trajectory design.

HOW GA IS APPLICABLE IN POWER SYSTEMS:

Since genetic algorithms are focused on the best survive concept, various approaches to improving. It is possible to propose enhancing the effectiveness of power system operations and increasing power output. Among these approaches, the optimum approach that resists all requirements can be chosen using genetic algorithms. The range of power system problems to which genetic algorithms have been applied is broad. Genetic algorithms are often viewed as function optimizers and if each chromosome is considered to represent a point (that is, an intersection of hyperplanes) in search space, it is seen that GAS differ from traditional search techniques in several ways.

1) GA's optimize the trade-off between exploring new points in the search space and exploiting the information discovered thus far.
2) GAS have the property of implicit parallelism, which means that the GA is in effect equivalent to an extensive search of hyperplanes of the given space, without directly testing all hyperplane values, information from current search points to direct subsequent search. Their ability to maintain multiple solutions concurrently makes GAS less susceptible to the problems of local maxima and noise.
3) GA's operate on several solutions simultaneously, gathering

information from current search points to direct subsequent search. Their ability to maintain multiple solutions concurrently makes GAS less susceptible to the problems of local maxima and noise.

THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN SYSTEM OPERATION CONTROL

Discrete control

(1) Cut load:

The load shedding is another kind of discrete control. When the system is disturbed or the generator is shut down, the capacity of the system is changed dramatically, while the load is kept at a high level, which is far beyond the system's supply, not to cause blackouts must reduce the load.

(2) Power system relay protection:

Relay protection is a kind of common discrete control, which is to detect and judge the normal or fault state in the system and can quickly react to the protection action. The ability to respond quickly and deal with the problem of AI has become an important tool for online assessment.

Continuous control

Continuous control system is also known as Excitation control. It is an important part of controlling the voltage and reactive power of the generator. It can maintain the stability of the power system in the disturbance environment. It is an important real time continuous control system against disturbance.

- Application of Artificial Intelligence in Transient Protection

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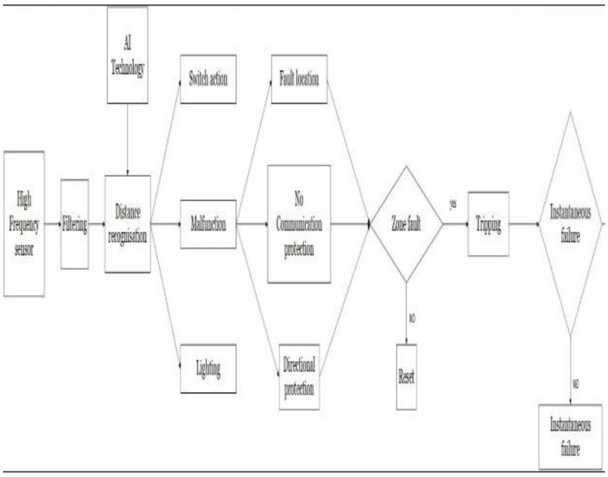

FIGURE 4: Block diagram of transmission line transient protection.

CONCLUSION

Table: COMPARISON OF AI TECHNIQUES IN POWER SYTEM PROTECTION

Property	Expert system	Artificial neural network (ANN)	Fuzzy logic
Comprehension used	Expert knowledge used is rules, objects and frames, etc.	Information extracted from the training set of cases.	The knowledge is in the form of protection criteria.
Troubleshooting and improving the relays	Requires change of rules	Difficult because its internal signals are difficult to interpret	Convenient, the internal signals are analyzable.
Self-taught	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	Simulation required is very large	Convenient and simulation is also required
Computations	extensive	Allocated hardware	moderate

Artificial Intelligence provides the key to a bright future in which we will all be able to make better judgments with the help of data and machines that comprehend our reality. The computers of the future will comprehend why switches need to be switched on as well as how to turn them on reliability is the major aspect of power system design and planning, and it was conventionally assessed using deterministic techniques. Additionally, conventional methods fall short of the probabilistic foundation of power systems. As a result, costs for operation and maintenance go higher.

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