Artificial Intelligence Techniques in the Smart Grid: a Review

Bezzar Nour El Houda, Meraoumia Abdallah and Houam Lotfi

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1st Bezzar Nour El Houda, 2nd Meraoumia Abdallah, 3rd Houam Lotfi
1st Electrical Engineering Department, Mining Laboratory
2nd, 3rd Laboratory of Mathematics, Informatics, and Systems (LAMIS)
University of Larbi Tebessi, Tebessa, 12002, Algeria
Address
1st nourelhouda.bezzar@univ-tebessa.dz
2nd ameraoumia@univ-tebessa.dz
3rd lotfi.houam@univ-tebessa.dz

Abstract—The smart grid or the new generation of energy came as an alternative to the traditional energy systems that no longer meet the increasing demand for electricity consumption with the increasing population, using bi-directional flows of electricity and information compatible with the capabilities of communication, advanced computing, control, and self-healing. It appeared to enhance the reliability and efficiency of power distribution with minimal impacts and to establish an automated power delivery network. Artificial intelligence (AI) has become one of the fastest-growing areas of technology and can play an important role in many applications, especially in the energy field. This paper provides a structured review of current research into some artificial intelligence techniques that can be applied to load prediction, power grid stability assessment, fault detection, and safety issues in smart grid and power systems, and aims to introduce the applications of artificial intelligence in enhancing and improving the reliability and flexibility of smart grid systems.

Keywords—smart grid, artificial intelligence, faults detection, load forecasting

I. INTRODUCTION

As the electricity market has been reformed renewable energy scenarios have been implemented, and the energy system presents the characteristics of openness, uncertainty, and complexity. Building the smart power grid has become a distinct trend and opportunity. [1] The smart grid is a transformation of the energy pattern from an electromechanically controlled system to an electronic one. The network systems consist of information management, control techniques, communication techniques, and field devices that coordinate electrical operations. These technologies, in turn, changed the planning and operational problems found in the traditional network to the ability to monitor or measure operations and to communicate data to operating centers. Some of the relevant problem areas in smart grids include load prediction, stability assessment, network security identification, and fault detection. AI Techniques support the digital power grid, through power system optimization, robust user behavior analysis, fault diagnosis, and more. The application of artificial intelligence faces many challenges and problems, including the lack of reliability, incomplete infrastructure, and the lack of algorithms for the energy industry. Artificial intelligence is a powerful tool to drive the smart grid more clearly. [2] Artificial intelligence techniques allow the use of staggering amounts of data to create intelligent machines that can handle tasks that require human intelligence. There are other ways to achieve artificial intelligence systems, such as machine learning, which is a branch of artificial intelligence, which are neural networks, robots, expert systems, and fuzzy logic, as we mentioned, despite the accuracy and reliability of artificial intelligence systems, it remains subject to many challenges in smart grid. Two types of artificial intelligence can be used, virtual and physical, and artificial intelligence systems in the smart grid are divided into artificial narrow intelligence (ANI) It is the only type of artificial intelligence that has been successfully achieved so far that is highly intelligent in completing the tasks directed at it, specifically designed to perform individual tasks such as facial or voice recognition, driving a car, searching the Internet. Artificial general intelligence (AGI) is the concept of a machine with intelligence that simulates human intelligence, whether in understanding or the ability to learn and solve problems. Artificial superintelligence (ASI) it is the superiority of machines over human intelligence. It is a source of inspiration for science fiction. The volume of artificial intelligence research and its applications in the smart grid has increased in recent years, and since it is not possible to provide a comprehensive review of techniques of artificial intelligence in the smart grid, whether in predicting the load or evaluating the stability of the power grid, detecting faults and ensuring network security, our paper presents some Techniques Artificial intelligence in some fields and sheds light on some potential future applications of artificial intelligence techniques. The remainder of this paper is organized as follows. Section 2 presents smart grid features. Section 3 surveys artificial intelligence techniques. Section 4 discusses some of the Artificial intelligence techniques in smart grids. Section 5 summarizes What is the future of artificial intelligence in smart networks.

A short summary conclude the paper in Section 6.

II. SMART GRID AND ITS FEATURES

Countries and various institutions know the smart grid with several definitions, but it is one definition. The smart grid is the network that allows the transmission of information and energy in two directions from each node in the network. It has an optimal performance that provides users with optimal services.

The different features of the smart grid make it possible to distinguish it from the traditional electric grid; the smart grid contains the following features [3]:

- Two-Way Communication.
- Integration Of Renewable Energy Resources (RERs) into The Grid
- Advanced Metering Infrastructure (AMI) System.
- Advanced Energy Storage Technologies.
- Data Management and Processing.
- Real-Time Operation and Control.
- Cyber-Physical Security of SG.

III. ARTIFICIAL INTELLIGENCE TECHNIQUES

Given the revolutionary transformation of the modern energy system, the components of the network have become more distributed, along with the infrastructure for metering and communication, where energy resources are integrated by including the energy network with the basic communication system. [4] To improve the performance of the smart grid by supporting wide applications such as distributed power management, [5] system state prediction, [6] and cyber-attack security, large amounts of data are placed due to the inability of traditional computational techniques to process the data of smart grid systems known to be in huge quantities as intelligence techniques artificial and others. To meet the challenges, many researchers have been wasted studying artificial intelligence techniques to improve the performance of the smart grid.

Artificial intelligence techniques in the smart grid are classified into the following areas:

A. Machine Learning

Is a term that refers to continuous learning and predictions from the data available. It consists of different algorithms that analyze the data to produce decisions or predictions regarding the current context through a set of instructions.

B. Deep Learning

Is a subfield of machine learning that deals with algorithms inspired by the structure and function of the brain called artificial neural networks. Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

C. Supervised learning

Create a mathematical model for the training data, which according to this mathematical model, where the supervised learning algorithms contain regression and classification algorithms.

D. Unsupervised learning

Recognize and describe the hidden data and rules in it so that unsupervised learning algorithms contain data of one class, grouping, and dimensionality reduction.

E. Reinforcement learning (RL)

Raising the system to the value of the output function, which is done by learning in some cases, and this learning has succeeded in areas we mention, including driving without a plane, and automated chess.

Traditional machine learning tries to put some laws in the samples and analyzes new data based on these laws. [1] Algorithms include traditional machines such as support vectors (SVM) and Bayesian methods.

IV. ARTIFICIAL INTELLIGENCE TECHNIQUES IN SMART GRIDS

The application of artificial intelligence techniques is divided into predicting the power load, [2] the application of artificial intelligence techniques is divided into forecasting the power load, Power grid stability assessments that include frequency stability, voltage stability, and small signal stability, then fault detection and ensuring the security of the smart grid.

A. Load forecasting

With the application of renewable energy scenarios such as solar energy, wind energy, and tidal energy, the uncertainty of the operation of the smart grid increases a lot. Forecasting the energy load makes the energy production and load identical in real-time and thus becomes important work for the electricity grid. Forecasting energy or energy load it is the discovery and determination of the strength of the demand in the network. [7,8] Forecasting is divided into three sections: Short-term (STLF), medium-term (MTLF), and long-term (LTLF), where the time ranges from a few minutes to a year or more.

TABLE I. TECHNIQUES FOR LOAD FORECASTING

Author (Ref.)	**Techniques**		
	Year	***Objective***	***Technique***
[12]	2017	STLF	RNN
[13]	2017	LTLF	LSTM
[14]	2018	LTLF	Fuzzy, ANN
[15]	2018	LTLF	LSTM, GRU
[16]	2019	MTLF	DBN
[27]	2019	MTLF	DNN
[18]	2020	STLF	CNN, Ensemble
[19]	2020	LTLF	LSTM, GRU

Author (Ref.)	Techniques		
	Year	***Objective***	***Technique***
[20]	2021	MTLF	LSTM, ETS, Ensemble
[21]	2021	MTLF	SVR

B. *Power Grid Stability Assessment*

It includes frequency stability (FSA), Transient Stability Assessment (TSA), Voltage Stability Assessment (VSA), Small-Signal Stability Assessment, or oscillatory stable assessment (OSA); [9, 10] the purpose of these matters is to ensure the reliability and security of the power system. The stability of a power system is the ability to remain in equilibrium. Traditional stability assessment models are complex and require large computational resources. Therefore, network stability assessment methods have been applied.

TABLE II. AI TECHNIQUES FOR THE POWER SYSTEM STABILITY ASSESSMENT

Author (Ref.)	Techniques		
	Year	***Objective***	***Technique***
[22]	2017	TSA	ELM, TF
[23]	2017	VSA	SVR, FL
[24]	2018	TSA	RNN, LSTM
[25]	2018	TSA	SVM, ANN
[26]	2019	TSA	SVM
[27]	2019	OSA	PSO
[28]	2020	OSA	CNN
[29]	2020	VSA	Decision tree
[30]	2021	VSA	Random Forest

C. *Faults Detection and protection of flexible equipment in power system*

Equipment based on power electronics technology is considered flexible equipment used in several fields, including alternating and direct current transmission, generation and storage of renewable energy, power distribution systems, small grids, and others. Diagnosing faults and protecting flexible equipment in the power system is a line of defense that ensures the safety of equipment, which in turn contributes to isolating faults quickly and avoiding the expansion of damage and error. [1] Deep learning can gain profound advantages in introducing new knowledge to expand the sample space and to express clearly the characteristics of equipment error at various levels.

TABLE III. AI TECHNIQUES FOR POWER SYSTEM FAULTS DETECTION

Author (Ref.)	Techniques		
	Year	***Objective***	***Technique***
[31]	2017	PV FD	PNN
[32]	2017	Line trip FD	LSTM, SVM
[33]	2018	Line trip FD	AE, SVM
[34]	2018	WT FD	ANN
[35]	2019	HIFD	ELM
[36]	2019	PV FD	GPR
[37]	2020	Line FD	ELM
[38]	2020	PV FD	ANN
[39]	2021	FD	Ensemble

D. *Power network security protection*

A Smart grid is a highly automated power transmission network that allows information and energy to flow two-way from each node of the grid. [1] Smart grid has more perfect performance and can provide users with a series of value-added services. The deep interaction of the information flow aims to make the power system in the face of many threats, as the network attack has the characteristics of strong concealment throughout the incubation period. Deep learning can identify network attacks, detect malware, provide protection, and ensure network security.

TABLE IV. AI TECHNIQUES FOR POWER NETWORK SECURITY PROTECTION

Author (Ref.)	Techniques		
	Year	***Objective***	***Technique***
[40]	2018	Survey	DL, RL
[41]	2019	Attacks detection	RL
[42]	2020	Survey	ML
[43]	2020	Survey	AI

V. FUTURE OF ARTIFICIAL INTELLIGENCE IN SMART GRIDS

Smart Grids aim to achieve full self-learning, responsive, adaptive, self-healing, automotive, and cost-effective. [11] Future directions or opportunities to achieve advanced smart grid systems are discussed as follows.

- Integration with cloud computing: The integration of artificial intelligence with cloud computing plays an important role in achieving smart grid systems by enhancing security and strength and reducing interruptions.
- Fog computing: Fog computing processes raw data locally and has multiple advantages such as energy efficiency, scalability, and flexibility.
- Transfer learning: [1] Transfer learning from training data requirements where researchers are motivated to use them to solve the problem of insufficient data.
- Consumer behavior prediction: With the help of fog computing, demand-side management has become a vital

task of management participation of users in energy systems. Energy consumption contributes significantly to the response to demand for the energy consumer side.

VI. Conclusion

The power system is in a revolutionary transformation from the traditional electric grid system to the smart grid system. In this case, the energy system methods dictate the advancement of suitable solutions Thus, artificial intelligence techniques are applied in smart grid systems with promising results. In this paper, we presented an overview of the modern applications of artificial intelligence techniques, which came in four areas (that is, load forecasting, power grid stability assessment, faults detection, and security problems). We also discussed the future trends of applying artificial intelligence techniques in the smart grid.

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