Cognitive Intelligence for Smart Grid Management: A Review

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Abstract

Realizing low-latency and high-bandwidth services is crucial to the advantages of smart cities when billions of IoT devices are streaming in them. Smart grids are developed from electric power networks and are characterized by increased resource availability and energy conservation. As hardware and software components advance, the decision-making process of current smart grids is changed to provide more reliable, cost-effective, and continuous systems for managing energy. This chapter examines cognitive intelligence techniques, the latest advancements in smart grid technology, and how cognitive intelligence interacts with smart grid management. A comparison of different cognitive intelligence techniques and smart grids, as well as the state of the global market, are also covered in this chapter. This chapter's primary goal is to assist researchers in identifying research gaps and understanding the state of the field's current research.

Keywords: Artificial Intelligence, Cognitive Intelligence Methods, Energy Efficiency, Energy Management, Machine Learning, and Smart Grids.

Table of Contents

1. INTRODUCTION

Through the redesign of current knowledge in cognitive sciences and technology, cognitive engineering offers a human-automation interface and assistance in making decisions. Via power transmission and distribution units, the power network is a complex structure that links several electric power generators from suppliers to consumers. Furthermore, it is anticipated that the next generation of electrical grids, known as smart grids (SG), will offer more benefits and services. Since the SG will be utilizing the most recent advancements in calculating, detecting, observing, and regulation methodologies, it is anticipated to be safer and more effective than the conventional electric grid. The SG's resilience and dependability will be increased by incorporating extra intelligence gleaned from the examination of statistics taken at various grid phases. Applying artificial intelligence (AI) approaches to the smart grid still presents numerous problems, although AI systems can be more accurate, dependable, and detailed. In the smart grid, artificial intelligence (AI) technologies can be either online or real. Informatics is a component of virtual AI algorithms that can assist grid managers in their work. Being self-aware AI platforms that can maximize and manage particular grid activities with or without human assistance are examples of real-life AI systems. Artificial general intelligence (AGI) and artificial narrow intelligence (ANI) are the two subcategories of AI systems in the smart grid. An AI platform that forecasts load using various databases is an example of an artificial intelligence (AI) system that has been created for a particular purpose with relevant needs and restrictions. AI systems designed to learn and change on their own, like people, are referred to as AGI. The methods of cognitive intelligence, the most recent developments in smart grid technologies, and the relationship between cognitive information and smart grid administration are all covered in this chapter.

There are six sections in this chapter: The adoption of smart grids and cognitive approaches is covered in *Section 1*. The comparative study of different cognitive techniques and smart grid systems is covered in *Section 2*. The results and discussion of contemporary advances in cognitive approaches, smart grids, and cognitive methods for managing smart grids are presented in *Section 3*. The market scenarios are described in *Section 4*, the opportunities and difficulties are described in *Section 5*, and the conclusion is described in *Section 6*. Now, in keeping with the subject, there are two topics of discussion: smart grids and cognitive approaches.

1.1. Cognitive Intelligence Method

As a subfield of AI, cognitive science focuses on the capabilities and technologies that enable our web pages, applications, and bots to see, hear, and communicate in natural language and comprehend customer demands. The term "cognition," which refers to the application of several forms of thinking, including decision-making, sensations, vocabulary, studying, understanding, and problem-solving, is the source of this description of cognitive sciences. AI anthropology, computing science, language study, neurology, psychological sciences, philosophy, and many other fields are all included in the broad category of cognitive research.

Their goal is to develop apps that can learn from humans, like:

- Talking and hearing, the capacity to convert text to audio and audio to text.
- The process of natural language. A computer must comprehend grammatical and semantic relationships in addition to keyword combinations.
- Being able to comprehend sensations and feelings ("sentiment analysis"). to develop sympathetic systems that can recognize an individual's mental state and base choices accordingly.

- The identification of images. This entails locating and recognizing things inside a picture or video clip. For humans, it is an easy task, but for machines, it is a significant difficulty.

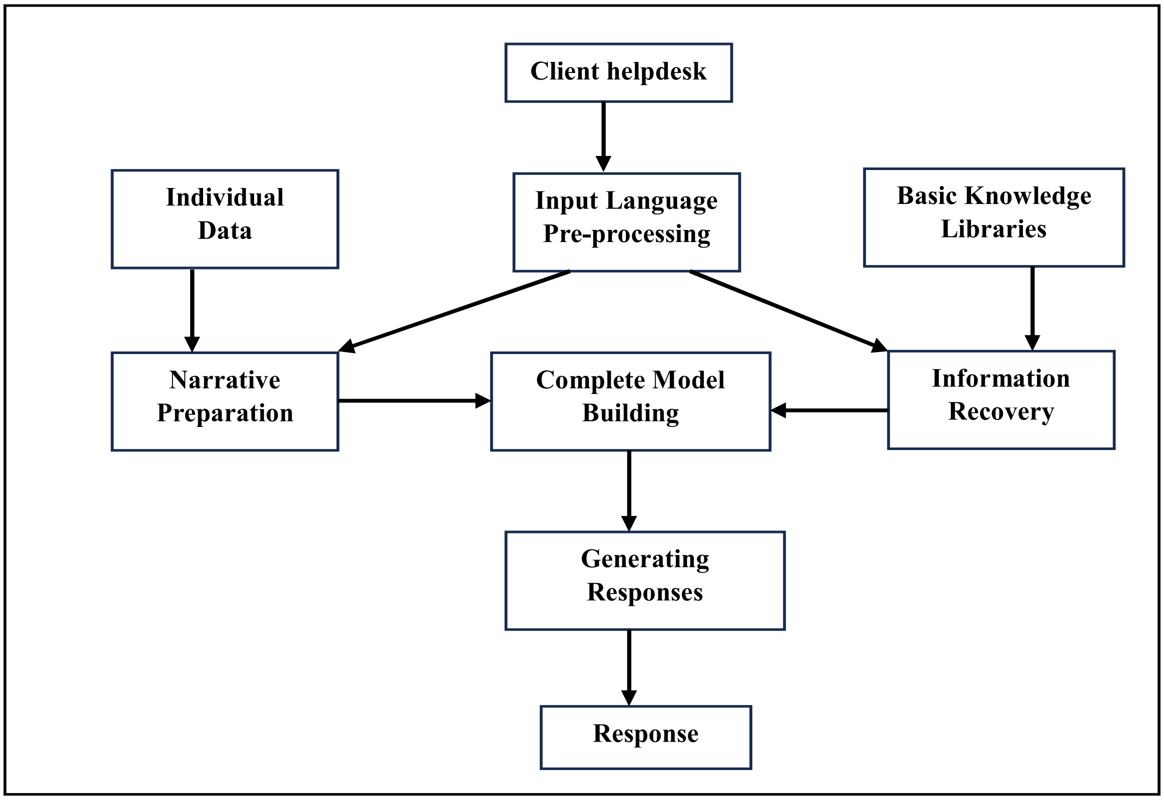

Figure 1: An overall cognitive unit framework

Cognitive intelligence includes brain skills such as understanding, remembering, argumentation, and solving issues. The primary categories of cognitive intelligence are listed as follows: Bodily-Kinesthetic intellect, Multilingual intellect, Musical intellect, Spatial intellect, Naturalism Intelligence, Physical-Mathematical Intelligence, and Relational Psychology. Cognitive intelligence has several benefits, including the capacity to solve problems, make decisions effectively, be flexible, communicate better, think creatively, and succeed in the workplace. Cognitive intelligence's drawbacks include excessive dependence on logic, anxiety, overanalyzing, a lack of psychological insight, pride and competition, difficulty acting, and inconsistent growth.

1.2. Smart Grids Analysis

Smart grids (SG) are electrical grids that efficiently balance the supply and demand of power in actual time while reducing costs and preserving the stability and dependability of the grid by employing digital innovations, sensors, and algorithms. Additionally, they detect and react to shifts through the usage of developing innovations. By doing this, they can maintain their operations and continuously modify supply to meet demand while providing power everywhere. Although smart grid technology is always changing, data is at the heart of it all: exchange of data, measurement, surveillance, and action. Smart meters communicate this data to the provider and the consumer in actual time, typically in half-hourly increments.

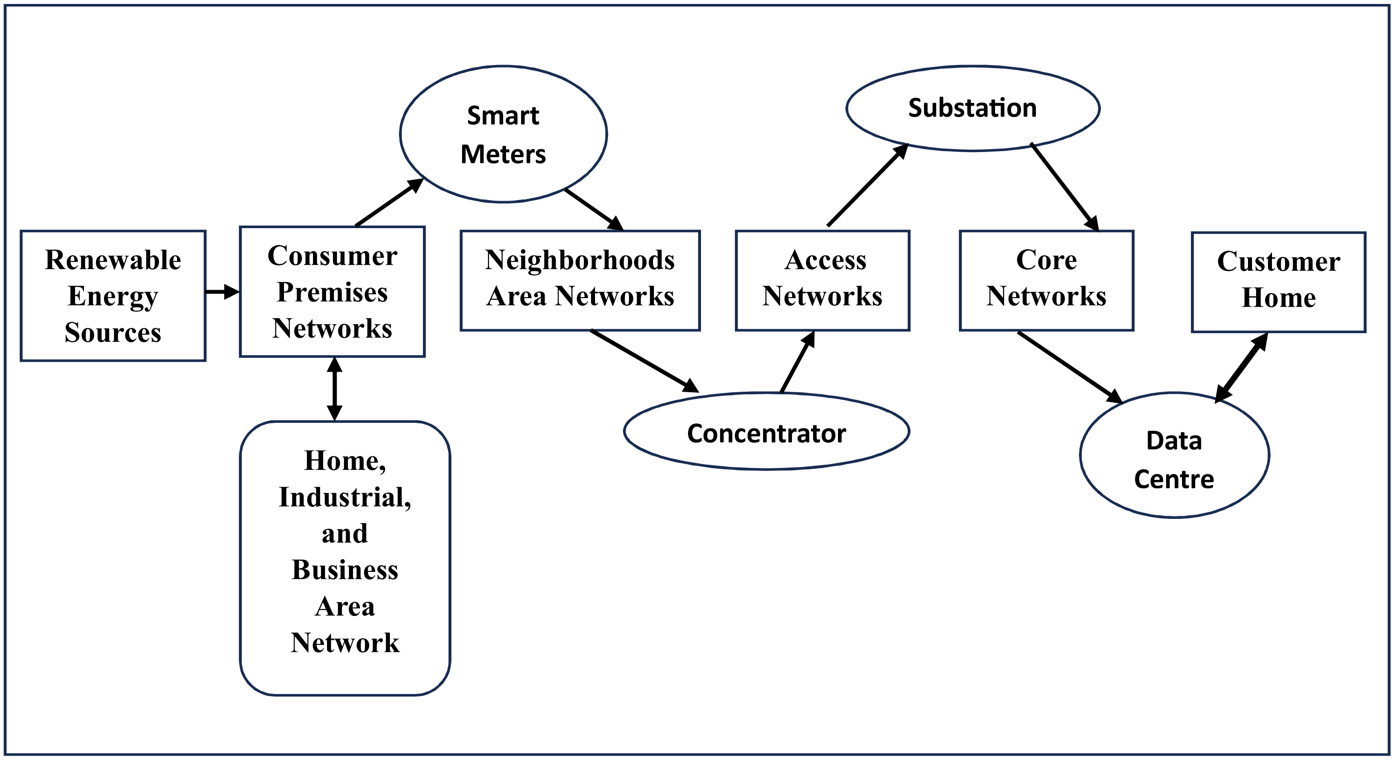

Figure 2: Framework of smart grids

To make sure that energy entering the grid won't harm electrical machinery, phasor measurement units (PMUs) keep an eye on variations in voltage or current. Digital protective relays: In the event of an emergency, these relays take action to safeguard the network. SGs are sophisticated electrical systems that effectively handle and disperse electricity by utilizing information and communication technology (ICT). The different kinds of SGs are as follows: Advanced Metering Infrastructure (AMI) Infrastructure Distribution Automation (DA), the SG Management System (GMS), SG Home Energy Management System (HEMS) and SGs Microgrid and SGs Renewable Energy (RES), Wide Area Monitoring System (WAMS), and SGs for Electric Vehicles (SGEV) Advanced Distribution Management System (ADMS) as well as SGs based on IoT.

Dependency, long-term viability, safety, green RES, cost-effectiveness, improved reach, reduced repair expenses, quick setup characteristics, and cellular connections equipped with robust safety mechanisms to protect data transmission are all benefits of the SGs.

SGs drawbacks include costly setup, network overload, interface difficulty, and technical specifications.

2. COMPARATIVE ANALYSIS OF VARIOUS TECHNOLOGIES RELATED TO SMART GRID MANAGEMENT

This section compares and contrasts different cognitive approaches, SGs, SGs networking mechanisms, and privacy-preserving strategies.

2.1. Comparative analysis of various cognitive intelligence methods

For several variables, including AI types, sources, techniques, algorithms, data, accuracy, speed, and hardware needs, Table 1 (a) lists a variety of computational techniques.

Table 1 (a): A comparative analysis of various methodologies

Parameters / Types	Types of AI	Sources	Approaches	Algorithm	Data	Accuracy	Speed	Hardware requirements
Cognitive methods	Supervised	Open	Informed decision	Inductive, deductive, incremental and non-incremental	Unstructured	45% to 95%	Very Fast	High-end machines
Artificial Intelligence (AI)	Supervised, and unsupervised	Open and Close	Problem-solving data	Artificial neural networks	Structure, and unstructured	70%	Very Fast	High-end machines
Deep learning (DL)	Supervised	Close	No structure data	Artificial neural networks	Large unstructured	97% to 99%	Fast	High-end machines
Shallow learning (SL)	Supervised	Open	Require limited data set	Low-level statistical algorithm	Structure, and unstructured	30% to 50%	Very slow	Low-end machines
Machine Learning (ML)	Supervised, unsupervised, and reinforced	Open and Close	Require structure data	Statistical algorithms	Structure, and unstructured	70% to 90%	Moderate	Low ends machines
Neural Network (NN)	Supervised	Close	Biologically inspired networks	Computational, and pattern recognition	Text data	87%	Moderate	High-end machines
Natural language processing	Unsupervised	Open	Rule-based approach along ML & NN.	Machine translation and speech recognition	Text, customer review, and speech.	95% to 98%	Very slow	Low-end machines
Computer vision	Unsupervised	Open	All the above approaches.	All above except SL.	Structured	50% to 98%	Slow	High-end machines

2.2. Comparative analysis of various cognitive intelligence methods

Table 1 (b)–(d) compares smart grids, communication technologies, and several SGs privacy-preserving strategies.

Table 1 (b): Comparison between different communication technology of SGs

Technology	Coverage range (km)	Spectrum range (GHz)	Data Rate (Mb/s)	Uses
ZigBee	0.025 - 0.045	2.4	0.25	HAN, AMI
GSM	0.5 -11	0.9 - 1.8	0.015	HAN, AMI, Demand response
GPRS	1 - 11	0.9 - 1.8	0.17	HAN, AMI, Demand response
3G	1.1 - 13	0.0019 - 0.00217	0.3 - 2	HAN, AMI, Demand response
4G	1 -14	0.6 - 2.5	15 - 150	HAN, AMI, Demand response
5G	0.5 - 15	30 - 300	100 - 20000	HAN, AMI, Demand response
Wi-MAX	1 - 50	2.5 - 5.8	74.5	HAN, AMI, Demand response
PLC	1 - 3	1 - 29.9	2 - 3	HAN, AMI, Demand response

Table 1 (c): Comparison between different types of SGs

Types / Parameters	Traditional power grids	Micrograids	Smart grids	Crowd energy	Distribution generation	EV based SG
Grid Topology	Radial	Closed system	Network	Radial	Network	Network
Reliability	Low	Medium	High	Very High	Medium	High
Operational efficiency	Medium	High	High	Medium	Medium	Medium
EV Integration	No	Yes	Yes	No	Yes	Yes
Monitoring and control	Not easy	Easy and moderate	Easy and fast	Complex but possible	Easy and complex	Easy and fast
Power quality issues	Very high	Moderate	Little	High	Moderate	High
Interoperability	Difficult	Yes	Yes	Yes	Yes	Yes
Power generation	Centralized	Centralized	Distributed	Distributed	Distributed	Distributed
Energy storage	No	Yes	Yes	No	Yes	Yes
Security	Very low	Low	High	Very high	Low	Medium
Renewable Integration	Possible but difficult	Possible	Possible	Possible	Possible	Possible

Table 1 (d): Comparison between features of different privacy-preserving techniques used for SGs

Parameters / Privacy-preserving techniques	Integrity	Confidentiality	Scalability	Computational cost/delay	Certification authority	Overhead
Secret Sharing	Encryption	Encryption	Yes	N/A	No	N/A
Z K Proof	Encryption	Encryption	No	Expensive	No	N/A
Homomorphic cryptosystem	BLS short signature	End to end Encryption	N/A	Not expensive	No	Low overhead
Third trusted party	Digital signature	Encryption MAC	N/A	Long setup time	Yes	N/A
Blind signature	Double encryption	Double Encryption	N/A	N/A	No	Depends on power usage
User-centric privacy	Encryption, HMAC	Encryption	N/A	400 msec	No	20 bytes

3. RESULT AND DISCUSSION

The latest advances in the fields of cognitive techniques research, smart grids, and cognitive methods for managing SGs have been covered in this section.

3.1. Recent Trends of Development in Cognitive Intelligence Methods (CIM)

A knowing graph design methodology that is secure and intuitive for SGs [1]. Including cognitive exercises in AI tests for big models [2]. Association of blood lead level with cognitive performance and general intelligence of urban school children in ten cities of India [3]. BrainCog is a CIM engine for brain-inspired AI and brain modeling that relies on spiking neural networks [4]. A comprehensive examination of the use of AI in cognitive load evaluation with operational near-infrared spectral analysis [5]. using cognitive digital twins (CDT) driven by productive AI to improve fabrication long-term viability [6]. A randomized the viability study of using AI as a virtual coach in a cognitive behavioral program for young people with idealization [7]. A socio-cognitive investigation in Spanish native authorities on AI, CIOs, and technical frameworks in public service [8]. A strategy utilizing understandable AI and DL for automatic evaluation of cognitive involvement in online discussions [9]. The Development, Structure, and Prospects of Product Architecture Assisted by CIM [10]. DL methods and AI algorithms were suggested for the advancement of higher education [11]. Transfer demand planning with AI for a business offering trade industry logistics support [12].

3.2. Recent Trends of Development in Smart Grids

SG and Industry 5.0 Collaboration: Uses, Difficulties and Alternatives, Power Measurement [13]. EV recharging location surveillance and prevention using an AI-enhanced SG arrangement [14]. Using a fuzzy multi-criteria look to assess SG investment drivers and develop effective strategies [15]. Attempts by False Information Injection on Data-Driven Techniques in Decentralized Power Supply SGs [16]. Evaluation of SG optimizing methods, Sensor Assessment [17]. Deep semi-supervised surveillance for power theft in AMI for safe and feasible SG [18]. An SG identity-based signature rule that is beneficial over lattices [19].

A novel real-time pricing for optimal DRP, considering price elasticity, and charging control methods of PHEV integrated with SGs, using GMO algorithm [20]. Analysis of renewable-friendly SG technologies for distributed energy investment projects using a hybrid picture fuzzy rough decision-making approach [21]. Renewable energy (RE) management in SGs by using big data analytics and machine learning (ML) [22]. Survey on blockchain (BC) for future SGs: Technical aspects, applications, integration challenges and future research [23].

3.3. Recent Trends of Development in Cognitive Intelligence for Smart Grids Management

SG Systems relies on Cognitive Radio [24]. Cognitive Radio (CR) SG interaction: An Overview [25]. SGs for Intelligent Communities Inspired by Cognitive Layout [26]. Home Area Networks (HAN) and SG Interaction [27]. Concept, Algorithmic methods and Safety of CR for SG [28]. A Review of Designs, Spectrum Access, and Difficulties in CR for SGs [29]. Ensuring technological advances to address spectrum incompetence is CR for SG services [30]. SGs Communicating with CR [31]. CR: A Creative and Effective Channel Allocation Method for SG Interaction [32]. Efficient Distribution of Resources in Cognitive SG Systems [33]. A Survey of the Potential Applications of Edge Computing for SG [34]. A Case-specific Reasoning Approach to electrical Network Reorganization for the SGs [35]. SDN-Controlled Cognitive Interaction Asset Distribution in the SG: Conducting IEC 61850 Message Exchange [36]. CR Network for SG: Microgrid Testbed, Control Algorithmic methods Safety, and Experimental Research System Layout [37].

Table 2(a): Analysis of recent developments in cognitive methods

Ref. No	Author Name	Publication Year	Objectives	Components	Methods	Limitation	Future Scope	ROC
1	H. Chen	2021	Performance parameter	SG performance parameter	Knowledge mapping innovation	No actual time analysis	AI techniques	1
2	Youzhi Qu	2024	Create a common basis for assessing large models' multifaceted cognitive ability.	Examinations of embodied, fluid, community, and refined intelligence in a fully complete online environment.	Increasingly complicated duties with cognitive science inspiration that were modified from assessments of cognitive ability.	Misunderstanding risk, difficulties with task layout, and scalability issues.	Focused simulation enhancements, thorough evaluation of AGI, and smooth assimilation into social life.	1
3	Diwas Kumar	2024	To evaluate hemophilia and blood lead levels using CIM	Socioeconomic status, anthropometric measurements, and mental assessments (CPM/SPM, coding, digit span, and math)	A cross-sectional investigation that used blood samples from 2247 students and intellectual tests.	Causality is limited by cross-sectional approaches, which might not take into consideration all confusing variables.	To reduce anemia and lead contact, and to carry out long-term research to confirm results.	1
4	Yi Zeng	2023	Create a framework for multi-scale brain modeling and AI prompted by the brain.	SNNs, brain regions, encoding, acquiring regulations, and hardware-software interaction.	For cognitive modeling and modeling, use SNN-based structures.	Higher mathematical requirements and difficulties simulating the brain accurately.	Develop robotics, AI, and biological intellect knowledge	1
5	Mehshan Ahmed Khan	2024	Categorize cognitive load with DL and fNIRS.	Attributes, hybrid designs, DL layouts, and fNIRS signals.	Examine investigations on the categorization of cognitive load via DL.	Hybrid DL for fNIRS data has not received much attention.	Develop hybrid DL designs for dependable fNIRS uses.	1
6	Fadi Assad	2024	Use CDTs to increase the sustainability of manufacturing	IoT, CDTs, visualization power data, and integrating GenAI.	Incorporate creative AI and information on energy into CDTs.	The complexity of CDT-GenAI incorporation has not been thoroughly explored.	Enhance CDTs for ecological impact and long-term viability	1
7	Catherine Johnson	2024	Assess AI as an online coach in self-help.	CBT sections that are AI-guided and entirely self-help.	Four-week randomization study involving college students.	Low survey response rates and tiny sample dimensions.	Tests with full power on the effectiveness of AI assistance.	1
8	J. Ignacio Criado	2022	Examine the scientific frameworks used by CIOs to explain AI in governance.	CIO views, AI tactics, and aspects of technological employ.	Sociocognitive evaluation of municipal CIOs.	Restricted to exploratory Spanish CIOs.	Test theories regarding the use of AI in government agencies.	14
9	Yuanyuan Hu	2021	Categorize cognitive participation in on the web debates automatically.	CNN, XAI visuals, unpredictability forests, and the CoI arrangement.	Examine CNN and random forest analysis in relation to different databases.	Only two disciplinary programs are covered, with mild precision.	For increased proficiency in classification, incorporate DL and ML	17
10	Wang Zuoxu	2022	Make use of CIM to improve the layout of goods.	Cognitive processing, allowing methods, and the CIPD scheme.	Provide a framework that connects design and CIM.	Restricted realm and design-related investigation.	Create industrial uses and human-like skills.	2
11	Amin Al Ka'bi	2023	Examine how AI can be used to improve higher learning.	Student participation in AI tools, and the suggested cognitive approach	Evaluation of the model with current computations for enhancement.	Legal issues, confidentiality, justice, and prejudice.	Encourage individualized learning strategies and analytical thinking	14
12	Krzysztof Nowacki	2024	Use AI to enhance logistics' organizing for transportation demand.	Inspection of case studies, AI techniques, and computational models.	Literature assessment, qualitative inquiry, and the use of AI in logistics.	Confined to a single case instruction; generalization.	Wider use of AI in logistics for transportation scheduling.	1
13	Sunawar khan	2024	Reliability and efficiency	Advanced Metering Infrastructure (AMI)	Blockchain technology	-	Real-time data analytics integration	1
14	Arvind R. Singh	2024	Data tampering, and cyber-physical attacks	Real-time intrusion detection and mitigation AL/ML	AI-SGF method, AI and ML algorithms	Performance parameter	Cybersecurity AI-SGF	1

Table 2(b): Analysis of recent developments in Smart Grids

Ref. No	Author Name	Publication Year	Objectives	Components	Methods	Limitation	Future scope	ROC
15	Hasan Dinçer	2024	Evaluated SG's investment motivators and provided clean power project legislation.	F–DEMATEL–W–WASPAS	Simulation of fuzzy collective decision-making	One important policy is to use monetary incentives to promote the manufacture of REs.	The primary motivator is internet safety, which is handled by appropriate legal processes.	1
16	Zengji Liu	2024	Parameter estimation of the DC/AC controller and the LCL filter.	Generative adversarial network (GAN)	Black-box false data injection attack (FDIA)	-	An experimental attack on the TSP strategy validated the efficacy	1
17	Stephy Akkar a	2023	Optimization methods used in the SG demand sector	Demand-side of SG model.	Optimization techniques used for SG.	Less accuracy.	Several types of dispersed power capital can be effectively coordinated by local power administration.	2
18	Ruobin Qi	2023	Electricity theft detection in the AMI of SGs.	AMI, CWT, DL.	Continuous wavelet transforms (CWT) to capture the time-frequency.	-	Deep convolutional autoencoder (CAE) and principal component analysis (PCA).	1
19	Longzhu Zhu	2023	An efficient identity-based signature protocol on lattices.	Algorithm Trap Gen and the algorithm Sample Mat	Proposed ID-based signature protocol for the SGs.	-	Performance Parameter.	2
20	Mei Li	2023	Decreased reactive power usage and improved voltage profiles.	Geometric Mean Optimizer (GMO) and actual time costing.	The three-tariff approach and other enhanced methods	Smart meter and distribution automation method .	Putting in HEV achievement metric	1
21	Hasan Dinçer	2022	Dispersed power investment project.	Complex proportional assessment (COPRAS), and picture fuzzy rough sets (PFRSs).	Hybrid picture fuzzy rough decision-making approach	Disaggregated trade data.	-	18
22	Noha Mostafa	2022	Framework of Big data in SGs and RE.	Random forest algorithm, Decision tree algorithm, Deep learning.	ML methods.	Dataset is considered relatively small for big data analytics	Bigger datasets with variety of RE sources and demand.	3
23	Charithri Yap a	2021	BC technology in SGs 2.0, which would facilitate a seamless decentralization process.	BC integration	BC and smart contract, AI, ML	-	M2M communication via 5G and 6G networks can minimize the energy imbalances.	18
24	N. A. M. Isa *et al.*	2013	CR integration in SG networks to increase the effectiveness of interactions.	Spectrum effectiveness, delay, and throughput	Assessment of cognitive radio conversation through simulation.	Lacks practical application and is restricted to mathematical evaluation	Use SGs with a variety of layouts in actual reality.	5
25	M. A. Ameen *et al.*	2020	Examine how CR is being used in SG to tackle QoS.	Service quality, latency, and bandwidth	Review of the literature on CR uses and innovations.	Lacks exploratory support for the methods under review.	Use cutting-edge AI in CR to make decisions in actual time.	4
26	S. K. Khaitan *et al.*	2017	Propose IoT and ICT-based frameworks for energy conservation in SGs.	Energy efficiency, cost savings	Framework proposal integrating IoT and ICT solutions.	Limited scalability for large-scale grids.	Extend to large-scale grids with robust IoT protocols.	2

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Table 2(c): Analysis of recent development in Cognitive intelligence for Smart Grids Management

Ref. No	Author Name	Publication Year	Objectives	Parameters	Methods	Limitation	Future Scope	ROC
27	A. Mahmood *et al.*	2015	Evaluate CR performance in SG home area networks.	Resilience, robustness	Performance evaluation using simulation tools.	Focuses only on HANs; lacks wide-area analysis.	Apply methodology to wide-area SG networks.	1
28	B. Wang *et al.*	2011	Explore conceptual foundations, algorithms, and security in CR for SG.	Spectrum utilization, security metrics	Analytical modeling and simulation of CR applications.	Limited discussion on practical deployment challenges.	Develop field trials and real-world deployment strategies.	5
29	S. Ghasemi *et al.*	2015	Examine SG obstacles, spectrum availability, and CR frameworks.	Spectrum availability and network structure	Extensive review of the CR platform texts.	Little attention was paid to the setting up of hardware.	Create hardware prototypes that will enable SGs with CR.	3
30	S. Maleki *et al.*	2012	Address spectrum inefficiency in SG using CR networks.	Spectrum efficiency	Simulation of cognitive radio-based communication protocols.	No experimental validation; limited to simulations.	Conduct real-world experiments to validate findings.	2
31	R. Deng *et al.*	2011	Apply IEEE 802.22 standard in SG wide area networks.	Latency, reliability	Use of IEEE 802.22 standard and CR for wide area network communication.	Limited to specific IEEE standards; lacks comparison with alternatives.	Explore other standards for enhanced performance.	1
32	M. A. El-Mougy *et al.*	2018	Propose intelligent channel allocation using CR in SG.	Channel allocation efficiency	Development of an intelligent channel allocation algorithm.	Algorithm complexity increases with network size.	Simplify algorithm for scalability in large networks.	12
33	H. Zhang *et al.*	2015	Address optimal resource allocation strategies in cognitive SG networks.	Resource allocation efficiency	Analytical modeling and optimization techniques.	Focused on theoretical models; lacks experimental validation.	Validate models with real-world data and scenarios.	10
34	Y. Zhou *et al.*	2022	Survey edge intelligence integration in SG.	Computational efficiency, reliability	Literature review of edge intelligence applications in SGs.	Limited to theoretical insights; lacks practical implementation.	Implement edge intelligence in diverse SG usage.	12
35	F. G. Calhau *et al.*	2019	Propose case-based reasoning for reconfiguring power networks.	Reconfiguration speed, reliability	Development of a reasoning algorithm integrated with HATSGA for power network reconfiguration.	Focused on simulation results; lacks field testing.	Field-test the proposed algorithm in diverse grid configurations.	2
36	Y. Moscovits *et al.*	2020	Manage bandwidth allocation for IEC messages using SDN/OpenFlow in SG.	Bandwidth utilization, latency	SDN-based cognitive resource allocation approach.	Limited to IEC messages; lacks scalability for other protocols.	Extend methodology to support multiple communication protocols.	5
37	L. Yang *et al.*	2019	Investigate CR networks for SG, focusing on layout and control instructions.	Architecture efficiency, control accuracy	Experimental system architecture with control instructions and security features.	Limited security evaluation; lacks robustness testing.	Improve security features and robustness under diverse grid conditions.	4
38	P K Dubey et al.	2023	Best DGs with EVs pairs.	Real power loss reduction.	Genetic algorithms.	Less accurate and small system.	High bus system.	4
39	P K Dubey et al.	2022	Review on DGs with EVs planning.	Performance improvement.	Various optimization techniques.	Less focus on parameters.	More objective parameters.	35
40	P K Dubey et al.	2024	Best DGs with EVs pairs for performance enhancement.	Loss minimization, current & voltage profile enhancement.	Genetic algorithms and Monte Carlo simulation.	Low bus System.	High bus system.	2
41	P K Dubey et al.	2024	Survey on DGs with EVs planning	Parametric enhancement.	Many techniques.	Low size system only.	High size	1

4. MARKET SCENARIOS OF COGNITIVE INTELLIGENCE AND SMART GRIDS

- By 2035, the global market for cognitive computing is expected to have grown from 50 billion dollars in 2024 to 780 billion dollars.
- Up until 2035, the global market is expected to grow at a rate of roughly 28% annually [42].
- In 2023, the Indian market for cognitive computing was valued at $10 billion. With an annual growth rate of 23%, it is expected to reach $14 billion in 2024.

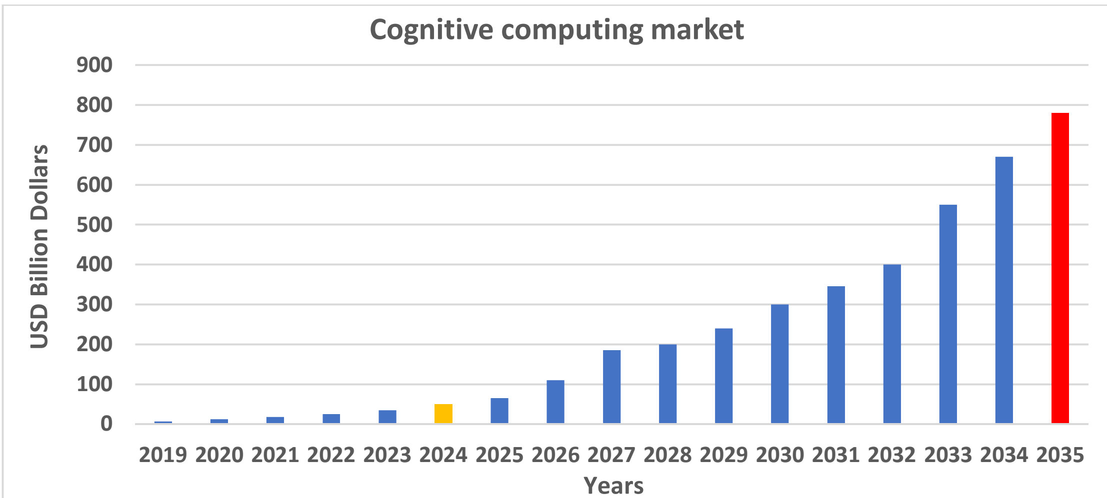

Figure 3 (a): Market growth projection of Cognitive computing in the world till 2035

- The size of the worldwide SGs market is expected to increase at an annual growth rate of 13%, from 41 billion dollars in 2024 to 110 billion dollars by 2032 [43].
- The size of the Indian SGs market was estimated at 0.6 billion dollars in 2023 and is expected to expand at an annual pace of 13% to reach 2.5 billion dollars in 2024.

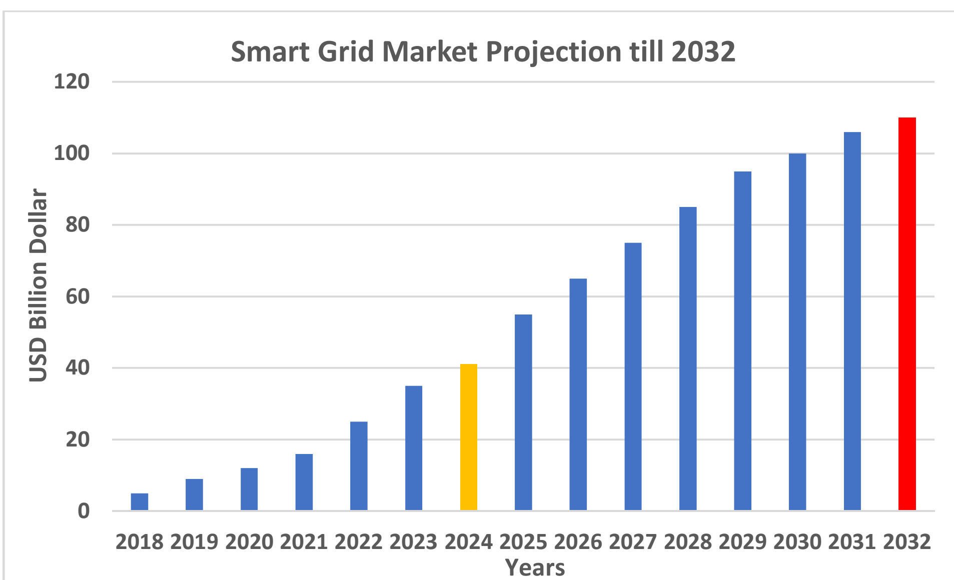

Figure 3 (a): Market growth projection of Smart Grid in world till 2032

5. CHALLENGES AND OPPORTUNITIES

Section 5.1 covers the challenges of cognitive techniques and smart grids, while Section 5.2 covers the opportunities of cognitive methods and smart grids.

5.1. Challenges of Cognitive Methods and Smart Grids

Challenges of Cognitive Methods	Challenges of Smart Grids
• Ecological validity is lacking.	• Cybersecurity risks.
• Reducist.	• High starting price.
• Unable to accurately assess cognitive function.	• Difficulties integrating technology.
• Disregard social and cultural influences.	• Encounters policy and regulation obstacles.
• Biased.	• Confidentiality and information management challenges.
• Prophetic self-fulfillment.	• Difficulties in instantly balancing supply and demand.

5.2. Opportunities of Cognitive Methods and Smart Grids

Opportunity of Cognitive methods	Opportunity of Smart Grids
• Discovering through cognition.	• Employments.
• Flexibility of thought.	• Decarbonization.
• Being forthright in cognition.	• Increased dependability and effectiveness.
• Develop your ability to solve issues.	• Availability of clean power.
• Improve the capacity for acquiring knowledge.	• More sophisticated metering systems.
• Outlets for creativity.	• Better level of assistance and peak load control.

6. CONCLUSION

Electrically powered incorporation is becoming more and more crucial. Utilizing adaptable power source incorporation tactics, the primary goal of integrating is to guarantee the uninterrupted and high-quality transmission of energy to the consumers. The research being examined looks at how the power economy is organized and how cognitive-based power systems are managed and planned. Our findings from this survey can be summed up as follows:

- AI strategies have been implemented in several usage fields that are essential to a SG endurance and dependability;
- Despite this, certain obstacles still restrict the use of AI methods in smart cities. A human-centered strategy for designing AI options and managing the "black box" nature of some AI approaches are significant obstacles.
- These findings should encourage debates in the usage areas examined in this chapter, which might further reinforce the interchange of suggestions.

In conclusion, SG systems' endurance and dependability are being increased through the use of AI techniques. This paper discusses the need for communication, data extraction, representation,

confidentiality preservation, and utilization forecasting innovations within the context of smart grids. There is a discussion of various levels of service standards and mechanisms. A contrast of the various applications of these advancements is shown. Numerous research issues are covered in detail, including grid features, research issues, and possibilities.
Interviewing the effects of AI techniques' "black box" nature on smart grid operations will be the main goal of our upcoming research in this field. We will specifically examine the ways in which smart grid operators have addressed this issue. A survey like this could assist researchers in creating more human-centered strategies for AI responses.

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