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A Theoretical Artificial Intelligence Framework for Electricity Generation Life Cycle

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Abstract

In human life, energy plays an indispensable role. The development of human society in some sense is inseparable from the development of high-quality energy and the use of advanced energy. Alongside economic and population growth, global energy production keeps growing, causing numerous dilemmas. Further, worldwide energy sector is facing enormous pressure to ensure stable and reliable power generation. In order to address these issues, various strategies have been developed over the past decades, however, they failed to meet the expected outcomes. Hence, this study adopted the Prisma methodological approach to develop an integrated theoretical artificial intelligence framework for electricity generation system. The proposed framework has the potential to assist the electricity utility to quickly track and respond on changes across the power grid and within the electrical energy distribution networks in real time. Further, it will help decision makers in energy sector to achieve efficiency in several aspects of their activities, from preventive plant maintenance to fuel-use decisions beyond.

A. Introduction

As a consequence of growing greenhouse gas emissions (GHG) rates in ambient ecosystems, global warming necessitates a decrease in the global usage of fossil fuels, which accounts for roughly 80% of global GHG emissions [1]. Substituting fossil fuel for green energies in power grids is also a concern because of the unreliable existence of green energy sources, such as wind and solar energy. Present electricity grids have a strongly regulated architecture that enables only a one-way transfer of electricity and data between producers and consumers, restricting the integration of decentralized and sporadic production of clean energy sources into networks [2]. Intelligent electricity grids, operated on the concept of bi-directional flows of power and information, offer increased energy demand and supply stability and can therefore support higher rates of renewables in electricity grids [3]. An active involvement of customers, whether by energy supply and/or the integration of energyresources, plays a key role in efficient smart grid's activity, as illustrated in the description of smart grids by [4]: "A smart grid is an electrical network that effectively incorporates the behavior and activities of all its linked users. This is a problem for the management of energy output and availability at all times. Weather awareness is then required to effectively adjust the energy market to weather instability and global warming.

Climate forecasts have, however, been constrained for many factors in the energy sector: broad range of available climatic databases, which are heterogeneous in terms of population classes and projections of greenhouse gases; inability to adjust contextual and geographical climate model resolutions for effect modeling; model bias; absence of consumer guidance; no customer-friendly database repositories [5]. In order to determine the feasibility of a potential wind farm, the wind power and photovoltaic capability factor, which corresponds to the proposed site for a future wind and solar plant, may be a guide for long-term pattern assessments and performance estimates. Oversupply variance measure calls for successful planning for potential adjustments in cumulative and seasonal data variations. Influx shifts impact energy costs and hydropower plant service optimisation [6]. For instance, environment projections often suggest normal winter temperatures and therefore a lower energy demand for heating. Together, these two improvements would authorize the usage of greater hydropower production and restrict spillage in the event that the reservoir ability is not big enough to hold excess water [7]. For areas classified as vulnerable to the possibility of freezing rain incidents, improved weather plans will also examine the effect of freezing rain on energy resources. An in-depth evaluation of incident period data, predominant wind patterns and weather research will help decision taking processes for future contingency steps. In the climatic time scale, the predictor for the conditions of bioenergy development lies in the season ideal for forest harvests. The energy demand predictor (estimated with population-weighted heating rates) seeks to help the energy sector forecast supply needs, thus helping to align high demand with weak renewable energy capacity [8]. In certain nations, in sure. France's energy usage is very much related to this measure, and a linear model will say a lot about the energy use variability in this situation [9]. Nonetheless, there are other drawbacks of use the dataset: issues related to the adequacy of the model outputs and energy requirements (e.g. wind speed of 10 m versus 100 m), availability of high-frequencies outputs, adequacy of spatial resolution model and energy requirements, drawbacks of bias correction (restors in many areas, unavailability of high-resolution measurement, project dependency [10]. To this end, this study develops an integrated artificial intelligence framework for electricity generation lifecycle.

To date, artificial intelligence is a critical catalyst for the automation of the energy sector, allowing the processing of vast volumes of data and refining increasingly complex structures. In the electricity sector, technological innovation effectively transforms data into value [11]. The skyrocketing value of AI in the energy sector will also be the product of development in two other technological patterns: decentralization and electricity generation. Decentralization is powered by the expanded installation of micro power stations, primarily solar photovoltaic (PV) rooftops, connecting to the power grid. Electrification of transport and houses (heating and cooling) requires a significant variety of modern loads, including electric vehicles, heat pumps and electric boilers. These emerging tools on the supply and demand side bring uncertainty to the energy system, rendering surveillance, governance and control critical to the sustainability of the energy transition. AI will benefit the renewable energy industry in a variety of areas, involving improved management, production and maintenance of renewable energy assets; more streamlined network operations and actual-time control; the introduction of emerging customer designs; and the creation of innovative business models. AI systems are independent and can work without human intervention and can learn and decide the way decisions can be made and draw specific conclusions based on the examination of various circumstances [12]. Investing in new AI-based technology was one of the key public sector approaches at different level of government in a number of countries worldwide. Nevertheless, while there have been many empirical research on this issue, the findings of this approach also need to be systematized. AI started to be quoted in research in the 1940s as to whether computers were able to determine [13]. Throughout the 1970s, practical AI approaches were developed and experiments were conducted throughout different areas [14]. More recently, the 2010s included many public sector studies and implementations [15]. Given the technical advances in AI, the government still provides services in an old way that can reflect the allocation of public spending, as the majority of the resources are for maintaining the existing structures [16]. This could rising public service trust and citizens' satisfaction, particularly in relation to private sector services [17]. The introduction of modern electronic systems will improve the efficacy and productivity of government and satisfaction of the public [18]. In addition, modern online technologies will make networking and interactivity simpler, while raising red tape [19]. The adoption of AI-based technologies by energy sector administrators has greatly increased in order to achieve savings in the delivery of energy to end-users [20]. Nonetheless, [21] point to the need to consider technical developments in the public sector and note that work into AI is still lacking. This thesis is inspired by a theoretical void in the literature in relation to public sector work and applications of AI. The work begins with the problem of government functions and thus the current research is intended to address the current situation in the field of AI technology and its implementations in the public sector in a standardized way.

B. Evolution of Artificial Intelligence

Minsky and McCarthy described AI as "a computer or program's ability to perform a task that would necessitate some kind of intelligence, if performed by a human being. [22] figured that the design, behavior, functionality, tasks and principles could be used to describe AI. [23] described AI as 'an operation that makes machines smart, and intelligence is the quality which allows a company to operate properly in the environment and with foresight. In addition, a lack of an appropriate and widely agreed definition may help to promote the development of AI. AI technologies could be related to human intelligence, in part through the question of addressing the interpretation, reasoning, understanding, and to a lesser degree emotional intelligence, and novelty of information. The AI definition is based on the premise that the human cycle of thinking can be highly automated. Just before the technological period, AI assertions was seen in various civilizations. In 1956, the word "artificial intelligence" was first introduced at Dartmouth College by American computer scientist John McCarthy and officially recognized as a research discipline [24]. The programs developed by AI have been very remarkable throughout the early years of AI development. Its contributions could have included solving algebraic word problems, geometry theorems and learning to speak English. AI science has attracted a lot of attention and support from government agencies over the same period. [25] argued that it was about then that in the WABOT venture in Japan the world's first complete-scale autonomous machine was produced. Although, AI is a challenging area and scholars did not know its importance in the past. Their expectations boosted the previous AI scores too high and the desired improvement was still not made. AI experienced numerous criticisms and economic failures in the 1970s, which culminated in significant reductions in work and funding [26]. This was also the first winter of the AI.

[27] stated that the first use of the Expert Programs in the early 1980s has brought AI science back from the brink. They was a big success at the onset. For one project, a specialist study called XCON yearly generated $40 million for 1986. This process, however, gradually would have been too costly to sustain. The key drawbacks of Expert systems have included the complexities of system upgrades and their fragility. It was the beginning of the second AI season. Nevertheless, after this time, the AI field did not emerge entirely. Rather, it continued to evolve under labels including artificial intelligence, cognitive systems. The modern era of AI eventually arrived in the last decade, which brought with it ever more rapid computing capabilities, especially parallel computing power, new sub- fields including Deep Learning (DL), Ma-chine Learning (ML), Artificial General Intelligence (AGI) and Big Data (BD).

2.1. Artificial Intelligence description

AI may be classified either on the basis of features or on the basis of their development over time. On the basis of its functionality, AI could be divided into constricted AI and general AI. Narrow AI can be used in several everyday activities owing to the vast number of applications that continue to evolve daily. Many of these activities involve arranging schedules, both private and corporate, reacting to consumer requests, conducting visual reviews of various services and infrastructure, tagging specific types of objectionable material on-line, etc. At the other side, Specific AI (or Artificial Artificial Intelligence) is somewhat unique and quite similar to the kind of emotional intelligence present in humankind. Such a system could execute operations that need more accuracy upon understanding and ac-accumulating practice. Up to now, Generalized AI can be used only in videos, and AI specialists are working to make this vision come true quickly. Another method of categorizing AI systems is based on the AI transition. As stated by [28] the early advancement of AI after its inception is identified as the old-fashioned of AI or, in other terms, Good-Old-Fashioned Artificial Intelligence (GOFAI). GOFAI was a theory that was established at the Dartmouth conference in 1956. Mainly focused on hand-coded abstract machinations, GOFAI was quite close to what conventional programming looks like. It is often referred to as symbol for its effort to explain knowledge in conceptual terms [29]. An-other of its famous euphemisms is Conceptual AI. Symbolic AI was designed to generate human-like knowledge in a computer, whilst most current studies in the area of AI emphasizes upon particular sub-problems.

The most effective type of Conceptual AI is an expert model. Of artificial intelligence, an expert program is a software program which equals or exceeds the decision-making capability of a professional expert [30]. Expert Systems were developed in 1965 and were some of the first fully popular examples of AI software. The purpose of such types of systems was to render the knowledge available for the program to function directly rather than indirectly. In other terms, the guidelines controlling the functioning of the expert systems needed to be specified in a way that was understandable and simple to manage. Therefore, even industry experts and not even IT (Information Technology) experts may be edited. The key benefits of this clear interpretation were quick growth and simple maintenance. The development of expertise is one of the main drawbacks of the Expert Programs. Certain issues involve implementation challenges, accessibility to vast repositories and quality issues [31]. Many scholars have offered various explanations why GOFAI could not bear the time test. The key point of these critiques was that the depictions used in the early GOFAI were not valid depictions of the modern world [32]. Another claim suggested that the reliance on logical analysis and inductive reasoning neglected other forms of reasoning.

Traditional subsets in the AI area include ML (Ma-Chinese Learning) and DL (Deep Learning). While the expressions AI, ML and DL are used synonymously in the literature, there is a strong difference between these three concepts. DL is a subsystem of ML which, in effect, is a component (or unit) of AI. One element that separates ML from typical information networks and expert structures is its capacity to develop and evolve on its own. ML can also render certain algorithms of its own. Arthur Samuel, one of the ML's founders, described it as "a research area that allows computers the opportunity to know without being directly programmed" [33]. DL is another branch of ML, which usually applies to large, artificial neural networks, and often large, reinforced learning. In DL, machines master the strategies that naturally come to humans. This is the main technology behind speech recognition, picture recognition, driverless vehicles, and so on.

2.2. How Artificial Intelligence function

The first theoretical solution to AI is the rule-based expert systems. This method fits the basic laws of the AI programs: if X, and then Y. A set of if-then rules expresses experience and information that fits well with clear, well-defined problems. However, this method falls apart when the number of possibilities increases dramatically in policy-making and where the laws disagree with each other [34]. Machine learning has been developed to address the shortcomings of the rule-based expert systems. As a subgroup of AI, machine learning algorithms also use statistical methods to adapt algorithms to conditions and "read" from data without being expressly configured to do it anyway [35]. Based on the probabilistic paradigm, machine learning algorithms reflect ambiguity — a central aspect of decision-making — via a probabilistic viewpoint. The state-of-the-art developments in probabilistic machine computing involve predictive programming, Bayesian optimisation, data encoding, and automated system development [36]. Considering, as a practical illustration, a manager choosing a plan from several options to be introduced in an enterprise. Any of the various interventions suggested for consideration by the committee leaders has an uncertain likelihood of implementation in the policy-maker's (in this case the leader's) company. When make a judgment, the leadership assesses the scenario by evaluating a variety of variables (e.g. the assets required to execute each plan, the performance rate of each system in other organisations, and the similarities between the leadership company and other organisations). The results of all these variables was then used to measure the likelihood of performance of each option plan in order to notify the decision-making process of the manager. Such a predictive method may be really useful for educational officials who do not realize how all the complexities of data processing and review affect the understanding of results. After all, even computer scientists often make incorrect judgments employing DIDM [37]. In this probabilistic method, AI algorithms produce valuable knowledge and make suggestions for DIDM members.

2.3. Artificial Intelligence strategies

AI is a computer science subset. Different academics describe AI in various ways. The variations in the AI concept include two dimensions: firstly, human primacy and secondly, rationality. The key element of intelligence is the logical behaviour. Through this view knowledge approaches the solution to problems by the laws of thought, that is to say by clearly defined reasoning processes (Aristotelian reasoning). The logical method leads to structures that incorporate mathematics and technology. AI also includes rationally operating systems. One concept of AI is: artificial intelligence is to investigate and perceive and act agents that exist in the world [5]. To this end, different AI methods have been designed and implemented in several various studies. These methods are presented and briefly listed in chronological order below.

A. The Analytical Hierarchy Process (AHP)

AHP developed by [32] is a common decision-making system. The benefits of the scheme include its positive mathematical properties, the simplicity of collecting the necessary input data and the fact that it is a decision-making method that could also handle complex questions. The organizational composition of the AHP comprises of requirements, sub-criteria, goals and options. Within AHP, dynamic issues should be first divided into elements that are organized into several organizational layers. For the next phase, policy-makers evaluate each clast in pairs depending on their expertise and information. Any degree of ambiguity can emerge when similarities are made by personal decisions. The greatest advantage of the AHP system is its ultimate process, named consistency verification. When the similarities have been rendered at all stages of the hierarchy and confirmed by the verification of accuracy, an aggregate priority classification is established that is focused on the value of each element and the related criteria rating.

B. Fuzzy Logic (FL)

Because FL is one of the simplest to grasp among the different AI strategies, the advantages of fuzzy logic (FL) are multiple. It is built on human language, and the benefits include its ability to draw on the expertise of specialists, its capacity to model multi-linear processes, its understanding to imprecise information, and, eventually, its ability to integrate with traditional control methods. The three key phases of the Fuzzy method are: fuzzification, intrusion and defuzzification [6].

C. Genetic algorithms (GA)

GA are strategies focused on the principle of fittest growth. Necessary approaches to the dilemma are referred to as "humans," and their progression in age is examined. The genetic algorithm uses triple primary providers: range, crossover and mutation [7].The fitness feature tests the capacity of each person to resolve the question, and this is repeated per phase in the reproductive cycle. The degree to which each person is duplicated is attributed to his health. In other terms, the further desirable an entity or a remedy, the better are the odds of his descendants being passed toward the next era. A GA conducts a particular replication of individuals to locate the possible solution to a question. Also the population with better odds of success continues to the next generation under the evolutionary theory of the fittest. Genetic operators assume the function of modern and enhanced descendants [8]. The method proceeds up to a given amount of years until an appropriate answer to the question has been discovered.

D. Artificial Neural Network (ANN)

ANN is a computational network or algorithm that is made up of artificial cells and could be used to design the biological endocrine system. Frank Rosenblatt introduced the first train-friendly NN, the Perceptron, at Cornell in 1957. At a NN, weight factors are generally used to model the relation between an input and an output vector. The model error is estimated during preparation and weights are modified with stochastic gradient descent or other steps to minimize the model error [9]. A multi-layered NN perceptron is an extension of an RNN [10]. It models time dependencies in target data through input links. By contrast with other methods, NN approaches are ideal for the simulation of multivariable problems [11]. Variables exhibit complex relationships among themselves in a multivariable problem. NN approaches are able to derive nonlinear associations by observing from the training data from variables. The strongest use of the NN was in the estimation of electrical load in houses.

E. Simulated Annealing (SA)

SA is another AI search or optimization strategy. This is a heuristic quest tool that chemists and metallurgists originally developed to determine the most stable condition in a chemical system [12]. By comparison to other iterative forms of development, SA requires fewer desirable options in the quest cycle, thereby stopping the task from getting wrapped up in local minima. [13] used GA and SA to optimize multi-module thermoelectric coolers and found that SA needed less time and energy in computation. Many of the above AI strategies are powerful and low. Similar to AHP or FL, GA is better at addressing complex issues. Fuzzy methodology is therefore effective in non-linear environments because it is easier to work with ambiguity and subjectivity [14]. The AHP could be really effective for decision support networks, being simplistic and comprehensive. SA should prevent local minima trapping of the quest. Recently, NNs are widely seen in ML and DL

C. Result and Discussion

The layout of the systematic literature review used in this study was built in compliance with the PRISMA protocols. The PRISMA approach involves excellently-defined steps of a comprehensive review, such as the establishment of eligibility requirements and the description of material sources, search methods, selection mechanisms, findings and data synthesis [15]. The current systemic methodology under the PRISMA paradigm includes the critical assessment of recent research in the area of artificial intelligence in the energy sector. This method has been used as it promotes detailed and factual information [16]. [17] defines the process of systematic analysis as suitable for the identification, evaluation and interpretation of the current body of scientific evidence. The systematic review is important to add value and examine the accuracy and discrepancies found in existing literature [18], which lead to the growth of theory, experience and knowledge [19]. The development and analysis of the evaluation method has been updated from [20] and [21] utilizing the [23] methods. Further, the choice of this approach is explained by the consistency of the protocols that make things simple to repeat and validate the findings [24]. The PRISMA procedures are divided into four phases: (a) identification, (b) screening, (c) eligibility, and (d) inclusion as shown in the Figure 1 below [25]. At the first stage that was based on the identification of relevant literature. To date, Literature analysis of the study's focus concepts, such as "Artificial Intelligence in the Energy Sector." This has been undertaken to insure that an effective search approach has been established as the search technique is compatible with the technical retrieval of specific documentation [26]. To order to create an initial understanding of the research field and to establish the nature of the analysis [27], various variations of search words were used in websites and databases. This method permitted the selection of relevant keywords for the analysis report, which therefore focuses on specific main area of interest, Artificial intelligence in energy sector. The search was conducted via SCOPUS database with an exact phrase in Title, Abstract, and Keywords as “Artificial Intelligence in Energy Sector”, “Artificial AND Intelligence AND in AND energy AND sector”. It came out with 336 articles. Further, came to the second stage. This stage consists of the search for literature and the compilation of the related articles for the research, based on the results of the search procedure for keywords. This method was carried out in four stages as shown in the Figure 1 below:

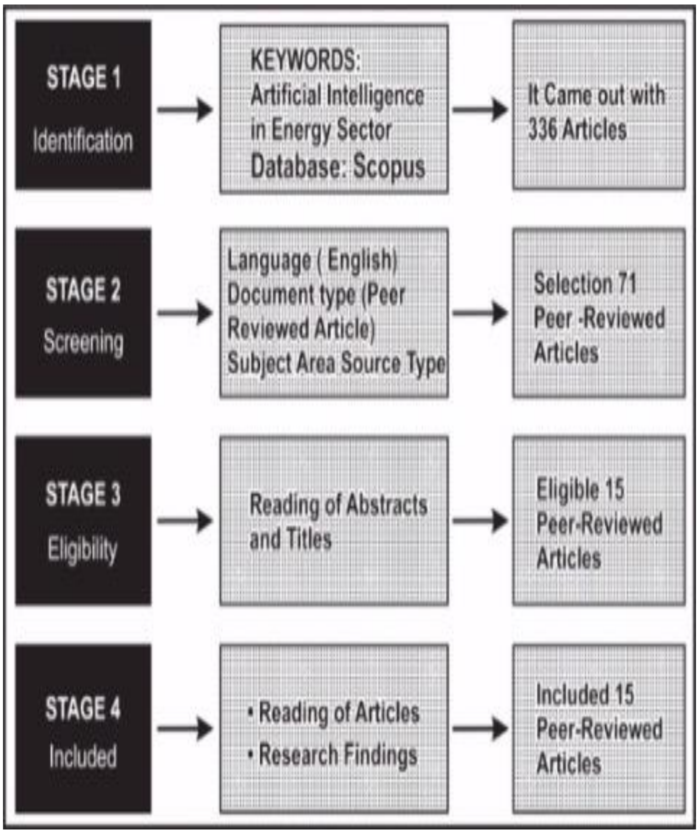

Figure1. Prisma method's flow diagram (author's own construction)

As shown in the Figure 1 above, subsequently, the findings of each phase were optimized on the basis of inclusion and exclusion criteria applicable to this analysis. As a consequence, in Phase 1, Scopus, was chosen for a literature review to ensure a thorough quest. The quest for the keyword was initially performed in the text, abstract in Scopus. The screening parameters used to remove possible papers related to this research from the corpus were; the compilation of papers from peer-reviewed publications since this approach contributes to higher content and scientific performance [28], the papers published in English, and no constraint on the year span because this analysis aims to investigate the phenomenon. The findings of the tentative quest in Step 1 produced a sample of 336 documents. Additionally, to order to ensure the quality of this study, the authors only used journal papers that were published in English only and excluded conference papers, book chapters, editorial reports, etc. The authors considered the timeframe from 2010 to 2020. The refinements of these two requirements resulted in 131 papers. Throughout abstract review, the collection of papers was focused on the role of Artificial Intelligence in the energy sector, which resulted in the completion of 15 articles as shown in Table 1 below:

Table 1. summary of the literature review (author's literature review)

Author & Year	Focus area	AI technics used	Outcomes

[8]	In this article, the Artificial Neural Network and the Genetic Method offer an intelligent scheduling algorithm. The pro-scheduling approach is targeted at reducing grid power consumption by 10%, 25% and 40%, according to weekly appliance schedules with a 15 minute increase.	ANN & GA	The technique offered decreases demand for energy in "first" times; maximizes the utilization of renewable sources (PV and wind turbines) and lowers grid dependency.
[14]	This article seeks, with a special attention on the industrial buildings sector, to foster the gap between high-level methods and the actual use of modelling algorithms. This is done by developing a revolutionary M&V 2.0 approach, which supports machine learning and allows for precise and reliable savings measurement.	ANN	The systematic approach lowers the requirement for extra metering facilities. This can minimize the necessary resources for a precise M&V in a specific project considerably.
[29]	The major aim of this effort was to decrease the number of such periodic evaluations in order to lower the maintenance costs of electrical lines. In particular, the aim is to decrease the number of regular assessments of transmission towers, to prevent step-by-step potentials that are particularly harmful to humans.	ANN & CBR	A sample of transmission towers from a specified set can be provided with the designed system for evaluation. The approach assures that the entire set has identical values without all transmission towers being examined.
[37]	The major aim of this study is to enhance sustainable energy planning procedures and provide a platform for additional GIS analysis rather than simulation of energy. The approach provided is to be integrated in a Space Decision Support System for energy decision-makers; by combining the currently existing data, it will assist to identify priority locations for regeneration initiatives	GIS	The main outcomes are the estimate and development of a technique which may be used at various scales of the geo referenced heating demand of residential structures for the research region (nearly 42,000 structures). Using the technique for the case study, the overall thermal demand of the building stock is overestimated somewhat,
[27]	This work offers an extensive and systemic analysis of the short-term forecasting approaches of artificial intelligence. This research aims mainly at reviewing, identifying, evaluating and analyzing the performance of the load forecast models and research gaps based on Artificial Intelligence (AI).	ANN	The findings in this research reveal that the training capacity of the neural network is clearly shifted toward promising load prediction model outputs than conventional methods.

D. Conclusion

From the table 1 above, it can be depicted that the energy industry is experiencing a significant transition with the increased installation of clean energy technology (solar PV and wind) offering intermittent energy supply, distributed energy systems, bidirectional electricity streaming, massive data flows captured by Internet of things as well as other tools, expanded usage of power storage, and the emerging function of electricity companies and customers. However, these measures are yet to address the current power crisis owing to a lack of an integrated holistic digital framework for the power system. Since, most system management actions are often made and executed manually or with a limited degree of robotics owing to a restricted amount of remotely responsive assets. Though, the aforementioned technological advancements will require a huge range of automatically manoeuvrable infrastructure to react to the demands of a variety of stakeholders (e.g. customers, utilities, transmission and distribution companies, suppliers). This innovative degree of control allows the network to be integrated for more distributed capital, thus optimizing device stability and lowering the cost of running a network for large shares. As a consequence, the function of AI is changing from a supporting and maximizing resource to a need for quick and rapid decision-making. As mentioned above, AI as an emerging technology will benefit the sustainable energy sector in a number of ways. Much of the innovations presently assisted by AI have been in the modeling and predictive maintenance of advanced environment and clean energy production. Throughout the future, AI would also improve decision-making and preparation, quality tracking, compliance, validation and supply chain management which would ultimately boost the performance of energy systems. Nonetheless, this overview reflects on promoting the deeper incorporation of AI into power systems, where Five key types of AI applications can be defined, as seen in Figure 2.

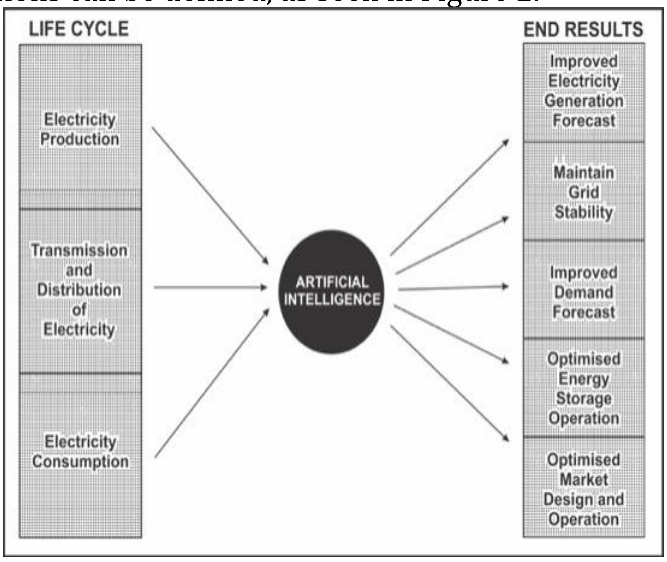

Figure 2. An integrated theoretical artificial intelligence framework for electricity generation lifecycle (own construction)

Enhanced meteorology is one of the key AI technologies that would boost the introduction of renewables into the electricity grid. Renewable energy sources generate an immense amount of information, and sustainable technologies have gained from long-established sensor technology. to this end, AI could generate reliable energy production predictions which would make it possible to incorporate even more solar and wind power into the grid. Since 2015, for example, IBM has demonstrated a 30 per cent increase since solar forecasts when collaborating with SunShot Program of the U.S. Department of Energy. The self-learning meteorological model and green energy forecasting technologies have combined broad databases of historical information and actual-time analysis from meteorological stations. Effective RES forecasts will help power stations and market factors to accurately predict their performance and bid on markets for wholesale and balancing while minimizing fines. For system technicians, reliable short term projections will improve the unit's contribution, improve transportation capacity and reduce maintenance problems, thus growing the machine's operational resources. From AI, both projects estimated power consumption utilizing data from solar sensors, wind turbine sensors and weather predictions, which helped reduce excess power consumption.

4.1. Improved electricity generation forecast

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4.2. Maintain grid stability

By delivering reliable demand and supply forecasts, AI may further improve the function of the grid, especially in the case of decentralized systems with bi-directional energy flow, which enhances the intricacy of the energy systems. Energy supply electricity companies face big challenges as the amount of renewable electricity production technologies, such as solar PV, has grown exponentially. The introduction of clean energy technologies contributes to volatility and intermittent peak loads in the electricity system. AI will guarantee that the electrical grid runs at an acceptable demand and will maximize the electricity usage of its consumers. Theoretically, the energy produced by the solar PV system will be used in the household or in the community grid. For instance, in Riedholz, Switzerland, four companies along with the Canton of Solothurn are exploring whether AI systems will guarantee potential grid reliability and reduce expenditure in expensive grid extension in the SoloGrid pilot project. The project explores whether GridSense, an algorithm which studies consumer behavior via AI, will 1) monitor primary energy users, like heat pumps, heating systems, home batteries for electric vehicle charging points, and 2) incorporate calibration data from solar PV systems for optimum grid performance. The algorithm constantly calculates variables such as grid demand, usage and output, namely weather forecasts and energy prices, and maximizes power production and consumption. The system lowers peak demands in the electricity grid, regulates demands and stabilizes the control infrastructure.

Grid instability at the electricity distribution stage is a significant consideration which decreases the introduction of wind and solar PV energy into energy systems. AI will increase the power grid efficiency and raising the need for new lines by allowing greater use of existing infrastructure as a feature of environmental conditions. This is the case, for instance, in the case of complex line ranking programs initiated by Ampacimon or under review at the Karlsruhe Institute of Technology in the "PrognoNetz" project. AI-based applications, utilizing vast volumes of weather information, will make optimum usage of current electricity grids by adjusting service to environmental conditions at any time and thereby reducing overload. AI may also boost the protection, stability and performance of the power network by automatically identifying disruptions. Operating system may allow autonomous data processing in real-time and identify scenarios of crisis or malfunction of the device. For instance, academics presented AI simulations with examples of typical system failures to enable the algorithm to slowly learn to discern – and precisely categorize – normal operating data from specified system malfunctions. The algorithm was able to make split-second assumptions as to whether there was anomaly fault, as well as the type and position of that disturbance. When one power plant collapsed, an immediate increase in the load on the other power plants might be anticipated. The added load speeds down the turbines and reduces the power. This calls for quick counter-measures (less than 500 milliseconds [ms]) since, if the frequency slips below the threshold value, the operator may be required to break off parts of the grid for the sake of network reliability. Since the algorithm would make a conclusion within 20 – 50 ms, there will be ample time to enforce the correct completely automated counter-measures. According to the study, the algorithm is able to be applied and work continues on the monitoring and enforcement of the related counter-measures.

4.3. Improved demand forecast

Accurate demand projections and RES predictions may be used to automate economic load flows and to boost demand management and performance. Consumers are generating an growing influx of data from the power grid itself. Considerable attempts have been made to deploy digital meters, which are capable of transmitting details to service providers as much as daily. Of this information, AI could forecast not only network demands, but also usage trends, and therefore can reliably create a trend of usage for each user. It becomes much more true with the recent installation of DERs, such as autonomous cars, heating systems and solar PV cells, something that fully alter the typical load form. Bee-Bryte, for instance, is a French start-up which employs AI to forecast a property's electrical energy consumption in order to deliver heat and cooling at the appropriate time, while preserving comfort and ventilation inside the consumer's operational range. It will lead in reductions of up to 40% on energy bills attributable to a mix of productivity improvements and transfers in loads to times where power is inexpensive where green power is active in the grid. Knowing user preferences, beliefs, desires and even personalities further improves the harmony and efficiency of the smart grid. This also encourages strategies to be implemented more efficiently and facilitates an awareness of the individual motives involved with the introduction of green energies and how to adjust customer behaviour to improve the electricity market as a whole.

4.4. Optimised energy storage operation

Power storage technologies are emerging as crucial enablers to clean power deployment in the context of large-scale batteries, aggregates ("behind the meter") or plugged-in electric cars.. AI will help run those systems in a more productive way, optimizing the introduction of renewable energy (along with the elimination of production projection inaccuracies), reducing locally generated power costs and increasing returns for storage facility operators. In the case of large-scale energy generation projects, which involves decisions on retaining surplus solar power in the battery network and on discharging batteries to satisfy demand at a later date, taking into consideration future output, renewable energy production, costs and infrastructure latency, among other factors. Since storage batteries could be triggered easily and could be used to control excess loads and reduce the back-up resources required from diesel generators, fossil fuel-fired power plants or other maximum power stations, AI could be employed to forecast and make decisions on energy storage management. The nature and sophistication of power storage facilities operation, involving several variables in a fluid environment, includes integrated AI. AI study investigates decision-making on a size and with a sophistication that outperforms those of a human operator, in particular for systems of hundreds of integrated power storage systems (electric power, kinetic, etc.) built on the customer side, in homes or in manufacturing installations.

In fact, AI could assist to measure and expand the lifespan of a storage device by employing computational logic algorithms to data recharging and unloading. Owners install their warehousing packs in conjunction with the cost of battery services and the effect such services have on battery safety. California-based firm Stem produces Athena, which employs AI to schedule energy consumption and allows consumers to monitor electricity variability in storage capacity. For example, Tesla's Hornsdale battery was a wake-up call in Australia in accordance with the US software company AMS. Through leveraging AI, flexible energy storage devices will maximize incentives to buy energy from the grid while rates are small and then sold back to the consumer while prices are inflated. The Hornsdal battery function through a Tesla-developed auto bidder, which enabled the project to catch the best income streams to an extent which human potential buyers alone could not achieve. "Comparable to an individual dealer, algorithmic bidding software will boost the battery turnover by around five times," as per AMS. During its first year of activity, the Hornsdale battery created an additional USD 24 million in sales, thus the ancillary service frequency control expense between USD 40 and USD 50 million, and thereby saving customers in the long run. Price reductions such as this will contribute to an explosion in algorithm production which is most profitable in order to run batteries.

4.5. Optimised market design and operation

Advanced AI-based technologies are now being applied to automate near-real-time marketplace activities. This modeling builds on the study of wide flows of different data to allow fast reaction to changes in the market. Intraday trading is extremely useful to adapt to sudden shifts in the energy supply and usage by utilizing market processes before managing supplies become important. This helps an operator of the electricity generating station who unexpectedly loses capacity in one block to purchase extra electricity from other market players to retain the balance block. Intraday trade is also a critical element for the direct selling of green energy as quickly evolving environment results in an unexpected shortage or deficit of electricity from RES. Within a competitive world that contains several factors, running intraday markets may be quick and complicated beyond the control of a human operator; this is the right scenario for sophisticated AI. As separate economies are combined to establish national economies, the difficulty of business operations grows even further. An AI-based algorithm named EUPHEMIA was established to measure day-to-day price of electricity throughout Europe and to assign day-to-day cross-border transmission power. EUPHEMIA is often used for coupled-day power rates for 25 European countries (Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom) with an average regular amount of the same. AI will improve time specificity on energy markets in terms of market architecture and enable for real time markets. The usage of AI in the fields of exchange and dispatch decisions for generating properties is being studied in near proximity to real-time commercial markets, with a view to ensuring that generators participate in business to optimize the benefit of versatile power choices. For instance, Origami Energy, a start-up firm based in Cambridge, UK, uses AI to forecast the supply of products and match market rates in almost real time in order to sell effectively in the transient response markets. By utilizing predictive analytics and deep learning, multiple organizational management challenges can be solved and new ideas can be extracted into medium and long-term planning – such as predicting when an asset would become available, the importance of versatility and the best means of deriving the greatest benefit from an asset.

E. Discussion and Conclusion

With the advent of intelligent appliances and associated software, and also the declining price of green energy, electricity users need an electricity supply system to be more smarter, safer and more efficient than ever. This need is entirely addressed by AI technology, which offers a decentralized sharing system for achieving renewable energy use and the establishment of a sustainable economy. This study attempted to respond to the use of AI technology in the energy sector. Today, the electricity industry is owned by South Africa government, and does not appear to favour the implementation of AI technologies. However, the cost of developing alternative energy sources is rapidly declining, creating major opportunities for the implementation of AI technology. since the electricity sector in South Africa still faces many technical and political issues. The AI technology itself is not yet established — not only in South Africa, but worldwide. The AI energy system is currently under investigation. Nonetheless, a regulation that is not adaptable to the business paradigm of the AI energy sector could be a greater challenge than technology. The restructuring of the electricity sector needs to be more deepened in order to establish the requirements for the development of the digitized energy network. In fact, the following protocol recommendations will be accepted by decision makers. First, the government of South Africa will enable businesses, universities and academic institutions to set up specific research platforms to study AI technology. Main fields of research cover cryptographic technologies, adaptive algorithms and risk management. Work will concentrate on seeking answers to concrete issues in South Africa. While there are some implementations of AI technologies in South Africa, the number of self-developed AI systems in South Africa is still fairly limited. Third, the government of South Africa will encourage the development of centralized household power production. South Africa's power distribution household lags behind developing countries. Household distributed power production is conducive to the widespread usage of AI technologies in the energy sector. Smart meters are used to record the flow of power between household appliances, photovoltaic cells, etc. Redundant produced electricity can be marketed to neighboring power users and can offer shared resource assistance to household users. In turn, distributed power generation will allow consumers to engage effectively in the development of renewable energy and the elimination of carbon emissions. Thirdly, the related legislation regulating the energy industry ought to be modified. Currently, most green energy ventures in South Africa need to be accepted by government, or businesses need to buy licenses, permits, etc. to carry out a project. As an significant driver for the energy market, so many connectivity and licensing laws do not hinder the smart energy network initiative. South Africa will change the expired Energy Act in order to render people and private firms liable for electricity supply. Where required, additional laws will be implemented to guarantee access to the power grid and the integrity of transactions. In fact, regulators could promote smart monitoring by adding AI technology itself to the management of the energy sector. Eventually, in order to safeguard competition in the energy sector, the government should simplify management measures as well as enhance quality and performance.

F. References

Articles must refer to at least 10 primary references published in the last 5 years. Writing a reference list must use the IEEE Mendeley style tool with the following conditions. [Cambria 12, space single]

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