Artificial Intelligence Integration with Energy Sources (Renewable and Non-renewable)

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Abstract: In the past decade or so, AI (artificial intelligence) technology has been growing with such a mesmerizing speed that today its presence in almost any industry that deals with any huge sheer volume of data is taking advantage of AI by integrating it into their day-to-day operation. Meanwhile, seven billion people worldwide shape the world’s energy system and directly impact the fundamental drivers of energy, both renewable and non-renewable sources, to meet the demand for electricity from them. These energy sources can be reached from nature such as solar, wind, etc., and human-made such as NPPs (nuclear power plants) in the form of either fission as an old technology since the Manhattan project and in the near future as fusion in the form of magnetic or inertial confinements. Meanwhile, AI controlling nuclear reactors are about to happen. The basic idea is to apply AI with its two subset components as ML (machine learning), and DL (deep learning) techniques to go through the mountains of data that come from a reactor, spot patterns in it, and calling them to the unit’s human attention operators is not invadable either. Designers of such nuclear reactors will combine simulation and real-world data, comparing scenarios from each to develop “confidence [in] what they can predict and what is the range of uncertainty of their prediction”. Adding that, in the end, the operator will make the final decisions in order to keep these power plants safe while they are in operation and how to secure them against cyber-attack natural or human-made disasters. In this short communication article, we would like to see how we can prove some of these concepts; then a NPP manufacturer can pick it up and use it in their designs of a new generation of these reactors.

Key words: AI, ML, DL, renewable and nonrenewable source of energy, fusion and fission reactors, SMRs (small modular reactors) and generation four system, IoT (internet of things), dynamic site, return on investment, total cost of ownership.

1. Introduction

Since about 600,000 years ago, when humans, for the first time, learned how to master the fire and used it to his advantage, energy became an integral part of his life. As time passed and technology advanced, the type of energies used has changed (wind, water, and wood). It was not until Industrial Revolution that the demand for energy changes substantially to the point that the existing energy sources were not enough. Some of the factors that contributed to this increase in demand were rapid growth of the human population, building new cities, factories, roads, bridges, etc. An increase in demand pushed humans to search for a new source of energy. The result was the discovery of coal. History shows that as time passed, both the demand for energy and looking for new sources of energy continued to grow.

Note that: Before the industrial revolution, our energy needs were modest. We relied on the sun—and burned wood, straw, and dried dung when the sun failed us for heat. For transportation, horses’ muscle and the power of the wind in our sails took us to every corner of the world. For work, we used animals to do jobs that we could not do with our own labor. Water and wind drove the simple machines that ground our grain and pumped our water (Union of Concerned Science). Wrigley also stresses that the shift from an economy that relied on land resources to one based on fossil fuels is the essence of the Industrial Revolution and could explain the Dutch and British economies’
differential development. Both countries had the necessary institutions for the Industrial Revolution to occur, but capital accumulation in the Netherlands faced a renewable energy resource constraint, while in Britain, domestic coal mines in combination with steam engines, at first to pump water out of the mines and later for many other uses, provided a way out from the constraint [1].

Energies can be classified based on many different characteristics that they have. In general, they are divided into two basic categories: renewable and non-renewable. Renewable or clean energy is a type of energy that comes from natural sources or processes that are constantly replenished. We also study the role of technology in renewable energies. The impact that renewable energies have on the environment and the advantages and disadvantages of each one, holistically, are discussed in this paper, while more details can be found by Zohuri and McDaniel [2].

Renewable energy, which is naturally replenished on a human time scale, is listed here as:

1. Sunlight,
2. Wind,
3. Rain,
4. Tides,
5. Waves, and,
6. Geothermal heat.

Renewable energy often provides energy in four critical areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) or rather or characteristic of the countryside rather than the town energy services [2].

According to the US Energy Information Administration, non-renewable resources are any resources that “do not form or replenish in a short period”. The most common non-renewable resources include fossil fuels like crude oil, natural gas, coal, and uranium nuclear energy in the form of the fission process and contrast in the near future, we can consider the commercial aspect of nuclear fusion as well [2].

In particular, these approaches apply to the new generation of these NPPs (nuclear power plants) both from fission and fusion generating energy prospectively and apply to Generation IV and possible futuristic Generation V of these plants. These generations are pushing the modulization of these reactors while getting their size and foot-print reduced drastically in respect to the previous generation of these reactors, notably the fission type NPP. See Fig. 1, where the history of these types is depicted by the invention of their generation historically.

Fig. 2 is the presentation of both renewable and non-renewable sources of energy by their types, selectively as well. Considering that integration of AI (artificial intelligence) as a complement and supportive element to its human partner is invadable in order to operate these new generations of reactors [3]. As we said in the abstract of this paper, the operation complexity of these new generations of fission/fusion reactors requires manipulation of many data and analytics that implementation of AI with its subsets such as ML (machine learning) and DL (deep learning) becomes a mandatory factor to their human partner.

The basic idea is that application of AI integrated with ML and DL techniques would go through the mountains of data that come from a reactor, spot patterns in it, and calling them to the unit’s human operators’ attention is not an invadable fact.

The nuclear industry in term of SMR (Small Modular Reactor) of Generation Four (GEN-IV) as well as aSMR (advanced SMR) (i.e., MSR (molten salt reactor) and ISMR (integral molten salt reactor)) in the past few years has gained much momentum and recently a lot grant dollar has allocated to universities such as North Carolina State University (e.g., a $3.4 million grant) by US DOE’s (Department of Energy’s) ARPA-E (Advanced Research Projects Administration-Energy) in the form of a research consortium to explore applications of AI for the technology associated with NPPs of advanced types.
Evolution of Nuclear Power

Fig. 1  Evolution of NPPs.

Integration of AI and NPPs.

Fig. 2  Integration of AI and NPPs.
DOE via its ARPA-E branch under a newly established task team was assigned to investigate and review the augmentation of AI and its status of this technology for applications in NPPs, as well as identify guidelines for AI work.

The task also was to identify the work required to allow the nuclear industry to realize the maximum benefit from the technology. The nuclear industry’s state was analyzed to determine where the application of AI technology could be of the greatest benefit.

As we stated, future NPPs are projected to be highly modularized, with the possibility of several NPPs being operated from one central control room.

Smart, centralized control centers are becoming handy-dandy for those mundane days by taking over human operator control with integrated AI-based system in place [4]. See Fig. 3.

When coupled with AI, the data can give the grid operators new insights for better control operations. It offers flexibility to the energy suppliers to cleverly adjust the supply with demand.

The advanced load control systems can be installed with the equipment, such as industrial furnaces or large AC units, which can automatically switch off when the power supply is low. Intelligent storage units can also be adjusted based on the flow of supply.

Additionally, smart machines and advanced sensors can make weather and load predictions that can improve the integration and efficiency of renewable energy.

AI-based diagnostics and control systems can make this possible by taking over the mundane day to day oversight tasks that the operators must perform to keep the plant running.

While still maintaining control of the plant’s plan, the operators can use these systems to do the simpler tasks, allowing the operators to concentrate on the more complex ones. The diagnostics systems will enable the operators to spend less time on actual signal monitoring, and more time on continuing activities such as interpretation of data compiled over long intervals.

One of the more useful aspects of the AI-based systems is explaining the reasons for the choices they have made and that they are recommending to the operators. The complete line of logic can be presented,
with nothing left out, and allow the operators to ensure that no oversights have been made. Deductions would be pre-checked and would be representative of a consensus of many expert system operators.

AI systems can help provide for redundancy and diversity, making nuclear plants as safe as they are. Any system developed can be checked by another system, which would use a different approach to be arriving at the solution than the first one, and any system would always be checked by the operators before anything would be done. Systems can be developed to constantly monitor plant functions, alter operators to problem conditions, and reduce the need for design conservatisms.

These are a few benefits that can be mentioned as a result of AI technology augmentation to the nuclear industry.

2. The Future of Energy

The energy future will be very different. For all the uncertainties highlighted in various reports by an expert in the field, we can be certain that the energy world will look a lot different in 2030 than it does today.

The world energy system will be transformed, but not necessarily in the way, we would like to see. We can be confident of some of the trends highlighted in reports on current global trends in energy supply and consumption, environmentally, and economically, as well as socially. But, that can—and must—be altered when there is still time to change the road we are on. The growing weight of China, India, the Middle East, and other non-OECD (The Organization for Economic Co-operation and Development) regions in energy markets and CO₂ emissions is something we need to consider dealing with global warming. The rapidly increasing dominance of national oil companies and the emergence of low-carbon energy technologies seem to be necessary solutions to the problem at hand, but not sufficient. Moreover, while market imbalances could temporarily cause prices to fall back, it is becoming increasingly apparent that the era of cheap oil is over. But many of the key policy drivers (not to mention other external factors) remain in doubt. Within all governments’ power, producing and consuming countries alike, acting alone or together, steer the world towards a cleaner, smarter, and more competitive energy system. Time is running out, and the time to act is now. So, what we need to ask is that “Can nuclear power compete?” [5].

A variety of companies that are in the energy production business say the answer may be yes. Manufacturers have submitted new designs to the Nuclear Regulatory Commission’s safety engineers, and that agency has
already approved some as ready for construction if they are built on a previously approved site. Utilities, reactor manufacturers, and architecture/engineering firms have formed partnerships to build plants, pending final approvals. Swarms of students enroll in college-level nuclear engineering programs, and rosy projections from industry and government predict a surge in construction. See Fig. 5.

Like another moon shot, new reactors’ launch after a 35-year hiatus in orders is certainly possible, though not a sure bet. The experts say that it would be easier this time because of technological progress over the intervening decades. But as with a project as large as a moon landing, there is another question: Would it be worthwhile?

To answer this question, we need to satisfy the four unresolved problems associated with nuclear power brought up by an MIT report [6].

To argue the first point, which is the cost of producing a NPP with its modern and today’s technologies from total ownership and return on investment, we need to understand the beast’s nature from the day it was born in the basement of the University of Chicago [6].

3. Fission and Fusion Nuclear Power Energy

By the nature of the nuclear process, we are able to generate two types of energy that are driven by this process, and they are:

1. Fission Process. Driving Nuclear Energy
2. Fusion Process. Driving Nuclear Energy

Each of these processes is heavily under consideration, and in the form of fission, commercially reactors are available beyond laboratory R&D (Research and Development). In this section, we holistically have described each of these processes and the types of reactors involved.

3.1 Fission Driven Nuclear Energy

Fission energy is not anything new in today’s technology. We have come to learn about Controlled Nuclear Fission Reaction since Fermi invented his first fission reactor in the basement of his office at the University of Chicago around 1942 [7].

In short, nuclear fission power plants (reactors) and nuclear fusion plants are producing commercial power tools. Fission power plants produce an extreme amount of energy by splitting heavy nuclei element cores, such as U-235, Pu-239. From a physics point of view, nuclear fission is a chain reaction in which neutrons are released, causing splitting of new lighter nuclei of other elements if they are not controlled by neutron absorbing material. Fission fuel and its product are so radioactive and have a high half-life. While dumping the produced waste from these power plants, one should make sure about the safety of the dumping area until a million years.

Over time, since Fermi’s invention, the fission reactors have gone through so much revision and generation as depicted in Fig. 1. Today, they operate commercially, in the form of LWR (Light Water Reactor) and PWR (Pressurized Water Reactor) that can be found in most modern naval vessels and submarines, particularly in USN (United States Navy), Russians and recently Chinese naval forces.

Today the Generation Three (GEN-III) of the LWRs are producing electricity as a source of clean energy [7]; however, these generations are at the end of
their life cycles, and recent accidents such as Fukushima Daiichi Nuclear Disaster have given a different perspective to this type of source energy driving electricity.

Lesson learned from accidents such as Fukushima has forced us to have a different way of thinking and to design the new generation, where the safety is number one priority and modularization of this generation known as GEN-IV is the front runner for the new fission reactor, where the modularization helps to reduce the foot-print of this generation to smaller real-estate. We have also been looking for an even smaller and smaller version known as micro nuclear reactor for space and military applications [8].

The advanced version of these new generations of four operating at a higher temperature (i.e., above 800 °C) is an excellent candidate to be integrated with a combined cycle of top or bottoming of open Air Brayton and Rankine cycles. With these configurations, the thermal output efficiency of these reactors makes them more cost-effective and provides a better TCO (total cost of ownership) and, consequently, an excellent ROI (return on investment) regarding renewable sources of energy [3, 9, 10].

Most six common suggested technical versions of these reactors are listed below as [3, 7]:

1. VHTR (very high-temperature reactor),
2. MSR,
3. SFR (sodium-cooled fast reactor),
4. SCWR (super critical water-cooled reactor),
5. GFR (gas-cooled fast reactor), and,
6. LFR (lead-cooled fast reactor).

Experts are projecting worldwide; electricity consumption will increase substantially in the coming decades, especially in developed countries with very high GDP (gross domestic product) around the world, accompanying economic growth and social progress that directly impact rising electricity prices. These countries have focused fresh attention on NPPs. New, safer, and more economical nuclear reactors could not only satisfy many of our future energy needs but could combat global warming as well. Today’s existing NPPs online in the United States provide a fifth of the nation’s total electrical output [7].

Taking into account the expected increase in energy demand worldwide and the growing awareness about global warming, climate change issues and sustainable development, nuclear energy will be needed to meet future global energy demand [7].

Fission NPP technology has evolved as distinct design generations as we mentioned in the previous section and briefly summarized here again as follows (i.e., Fig. 1):

- First generation: prototypes, and first realizations (~1950-1970).
- Second generation: current operating plants (~1970-2030).
- Third generation: deployable improvements to current reactors (~2000 and on).
- Fourth generation: advanced and new reactor systems (2030 and beyond).

The Generation IV International Forum, or GIF, was chartered in July 2001 to lead the world’s leading nuclear technology by nations’ collaborative efforts to develop next-generation nuclear energy systems to meet the world’s future energy needs.

Eight technology goals have been defined for Generation IV systems in four broad areas:

1. Sustainability,
2. Economics,
3. Safety and reliability, and finally,
4. Proliferation resistance and physical protection.

Many countries share these ambitious goals as they aim to respond to the twenty-first century’s economic, environmental, and social requirements. They establish a framework and identify concrete targets for focusing on GIF Research and Development (R&D) efforts.

As we stated above, eight technology goals have been defined for Generation IV systems in four broad areas: sustainability, economics, safety and reliability, proliferation resistance, and physical protection [7].
3.2 Fusion Driven Nuclear Energy

Since the discovery of Plasma as the 4th state of matter, where the gas is in ionized form, our attention toward thermonuclear fusion power has been expanded as a new source of clean energy, and that is why perhaps it can be categorized as a renewable source of energy, thus controlling thermonuclear reaction driven energy and thus, producing electricity to meet our present and future demand for energy driven electricity [4].

Note that: Matter in nature can be found as Solid, Liquid, Vapor, and finally, if the temperature increases where the vapor starts getting to be ionized is called Plasma.

What is going on, for example, at the surface of the sun and all stars within the Galaxy is hot Plasma (Fig. 6) interaction taking place to generate heat, and that is what we are trying to achieve—a controlled process version of this interaction on earth, as means of producing clean energy with the unlimited source.

However, to achieve these controlled fusion reaction devices on earth as a goal, it would be a breakeven achievement that falls under Lawson Criteria [11-13].

The point reaching breakeven is basically called for the energy being released via fusion reaction that equals the amount of energy being consumed to maintain the plasma reaction.

The ratio of input to output energy is denoted \( Q \), and breakeven corresponds to a \( Q \) of 1. A \( Q \) of at least one is needed for the reactor to generate net energy, but for practical reasons, it is desirable for it to be much higher (i.e. Lawson Criteria).

The theory of fusion fundamentally works based on the nuclear fusion concept that relies on two elements of light atomic nuclei to form heavier ones such as helium. As an example, we consider two isotopes of hydrogen, namely deuterium (D) and tritium (T), to be fused together to produce helium (He), producing clean energy, and so long as we have access to ocean water around us, then we have access to such unlimited sources by extracting both D and T from the ocean water.

![Fusion interaction of plasma taking on sun surface.](image)

As far as fusion driven nuclear energy is concerned, presently, two types of fusion are under studies by the scientists and engineers, expert in this field, and they are:

1. MCF (magnetic confinement fusion).
2. ICF (inertial confinement fusion).

Among these two types of confinements, there are many different suggested nuclear power fusion reactors at the laboratory level that these scientists and engineers are experiencing and trying to push to the commercial stage.

In this part of this section, we define first MCF and its associated R&D reactors, and then, we take a look at ICF and the kind of research, which has been taking place to demonstrate the commercialization of such reactors in the near-future time frame. Both these matters are approached here holistically, and we encourage those readers who are interested in more granular information to refer themselves to one of the appropriate references at the end [11-13].

In the case of MCF, we are taking advantage of the electrical conductivity of the Plasma to contain it through interaction with magnetic fields by applying Lorentz force and follow a helical path along the field line as illustrated in Fig. 7a.

As Fig. 7a illustrates, one can take advantage of the toroidal field and the coils (Blue) that produce it, the plasma current (Red) and the poloidal field created by it, and the resulting twisted field when these are overlaid.
A typical toroidal machine concept, also illustrated in Fig. 7b, is a pinch-effect to drive the control fusion reactor [11, 12].

Tokamak (i.e. a Russian word, means donut shape) reactor and Stellarator were the two devices that offered such solution as illustrated in Figs. 8 and 9.

As we mentioned, the Tokamak solution was one of the first devices suggested for MCF (magnetic confinement fusion) driven fusion in a controllable...
Inertial confinement fusion (ICF) is a process that uses a high-powered laser to compress a small pellet of fuel, typically a mixture of deuterium (D) and tritium (T), to achieve high temperatures and pressures necessary for ignition and thermonuclear fusion. The process is designed to ensure that the fuel is compressed to a density and temperature high enough to initiate a thermonuclear reaction.

The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in Livermore, California, is a key project in the field of ICF. The NIF uses a system of 192 lasers to heat and compress a deuterium-tritium (DT) fuel pellet to near-ignition conditions. The goal is to achieve a state where the fusion reaction releases more energy than is required to drive the lasers, making the process self-sustaining.

ICF is one of the technologies being explored for achieving nuclear fusion, which is the process that powers the sun and stars. Unlike traditional fusion reactions like those in nuclear fission, ICF does not rely on a controlled nuclear reaction but instead uses high-energy lasers to compress and heat a fuel pellet to fusion temperatures, allowing fusion to occur naturally.

The NIF is designed to achieve ignition, which is the point where the fusion reaction in the fuel core releases more energy than the lasers used to compress it. This is a critical step in the process of achieving nuclear fusion as a viable energy source.

In this process, a droplet of fuel is formed and compressed in a way that mimics the conditions inside a star. The high-energy lasers are fired at the target, causing the fuel to compress and heat up. As the fuel reaches the ignition temperature, the thermonuclear reaction begins, releasing a large amount of energy. The process is monitored and controlled using advanced imaging and diagnostic techniques to ensure the successful compression and ignition of the fuel.

Inertial confinement fusion is considered a promising technology for achieving nuclear fusion on Earth due to its potential for higher energy output and more efficient fuel usage. However, significant research and development are still required to optimize and scale up the process, making it a viable power source.

Inertial confinement fusion is a complex and advanced technology that involves the use of high-powered lasers, precise control systems, and sophisticated diagnostics. It represents a significant step forward in the quest for a clean and sustainable energy source through nuclear fusion.
In conclusion, AI, in conjunction with HPC (high-performance computing) is approaching points to bright for fusion energy in the near future.

Due to the nature of experimental approaches and cooperative data as well as images that are required to be analyzed by scientists and engineers involved with new Generation IV (GEN-IV) in case of fission process driving energy production and fusion in case of both MCF and ICF deal also a lot of data analytics and image processing analysis, thus usage of a super-computer of HPC type becomes a mandatory requirement. See Fig. 14.

Researchers are using DL techniques on DOE super-computers to help develop fusion energy.

As we stated above, to ensure Plasma—the fourth fundamental state of matter—retains its heat and does not interact with materials in the containment vessel, researchers employ doughnut-shaped fusion devices called Tokamaks, which use magnetic fields to trap fusion reactions in place. However, large- or exa-scale plasma instabilities called disruptions can interfere with this process.

Science simulation, visualization, data, and learning applications will greatly benefit from the massive computational resources available with future exascale systems. Researchers in the ALCF’s (Argonne Leadership Computing Facility’s) Aurora ESP (Early Science Program) are blazing the trail toward reaping those benefits from the US DOE’s Argonne National Laboratory’s upcoming Aurora exascale super-computer.

4. Nanotechnology and Energy Storage

Nanotechnology creates and manipulates matter at the molecular level, making it possible to create materials with improved properties, such as being lightweight and having ultrahigh strength and greater capabilities such as electrical and heat conductivity. Many applications are possible for the energy industry. The oil industry already uses nanoscale catalysts for refining petroleum. Nanoparticles with unique catalytic capabilities are being researched to refine thick, gooey oil sands into highly refined oil more effectively and efficiently.

Nanotechnology may be a promising solution for the transmission and storage of energy, particularly electrical power and hydrogen. Nano-based materials may create new opportunities to transport electricity efficiently and at a lower cost over very long distance.

In this unique and yet very new industry, AI also plays a significant role in enhancing performance and applying it, even in the nuclear industry.

Furthermore, Aurora and the next generation of Exascale super-computers will apply HPC and AI technologies to even cancer research and climate.

In the end, science at the exascale level is the future of both fission and fusion of today and the future technology of these two processes.

5. What Are AI, ML and DL?

The past decade up to now has encountered a new revolutionary technology that seems to have many applications across the entire industry (Fig. 4). This innovative technology is called AI that has been driving business intelligence to a different level, considering any business operation with a magnitude of incoming data to be analyzed. These business day-to-day operations with a share volume of data (i.e., Big Data) require augmentation of AI in conjunction with HPC.

Even the energy sector, both renewable and non-renewable sources, is in need of AI in need of their data analytics and data predictive [14], respectfully. This section briefly defines what the AI is and what other components are involved with AI system to make a business operational in a resilience model—a good BRS (business resilience system) [15].

In a very holistic way, AI by today’s definition is known as narrow AI (or weak AI) [16].

This kind of AI (Fig. 15) is designed to perform narrow/simple tasks such as facial recognition, internet searches, or driving a car in an autonomous mode.
To recap, AI is intelligence demonstrated by machines, unlike the natural intelligence displayed by humans and animals.

In other words, AI that is the new buzzword of the market of technology, is the science of making machines as smart and intelligent like human as an ultimate goal, to the point that we go from a weak AI to super AI.

Such progression within the domain of AI by definition is the ability of a computer algorithm or program, particularly in the case of HPC or machine, to think and learn very similar to the human being. Two distinguished points about us as human, are that we can think logically and fabricate physically (i.e., Homo Sapiens or “Wise Man” in Latin and Homo Fabian or “Man the Maker”).

With this basic understanding of AI, there are certain key factors one should know about AI:

- It is essential to distinguish different types of AI and different phases of the evolution of AI when it comes to developing application programs.
- Without recognizing the different types of AI and the scope of the related applications, confusion may arise, and expectations may be far from reality.
- In fact, the “broad” definition of AI is “vague” and can cause a misrepresentation of the type of AI that we discuss and develop today

Different types of AI are illustrated in Fig. 16.

One of the significant advantages of AI is the capabilities that make it possible for machines to learn from experience, adjust to new inputs, and perform human-like tasks. Most AI examples you hear about today—from chess-playing computers to self-driving cars—rely heavily on DL and NLP (natural language processing) [16]. Using these technologies, computers can be trained to accomplish specific tasks by processing large amounts of data and recognizing patterns in the data.

AI will play in our fast-paced life, and modern technology that we encounter in our day-to-day life is essential.

Furthermore, integrating AI within technology as a wide range of smart tools these days, while partnering with humans [17], enables people to rethink and gather information, analyze the data, and finally, utilize the resulting insight to have a better-informed decision. These days, AI is essential since the amount of data generated by humans and machines far outpaces humans’ ability to absorb and interpret the data and make complex decisions based on that data.

To understand how AI works, one needs to deep dive into the various sub-domains of AI (i.e., Fig. 3) and understand how those domains could be applied to the industry’s various fields.

ML is the branch of AI that holistically addresses to build computers that automatically improve through experience. Indeed, ML is all about the knowledge from the data. It is a research field at the intersection of statistics, AI, and computer science and is also known as predictive analytics or statistical learning. Indeed, ML’s main idea is that it is possible to create algorithms that learn from data and make predictions based on them. Recent progress in ML has been driven
by developing new learning algorithms and theory and the ongoing explosion in online data availability and low-cost computation.

With big data growth, ML has become a significant and key technique in solving problems. ML finds the natural pattern in data that generates insight to help make better decisions and predictions. It is an integral part of many commercial applications ranging from medical diagnosis, stock trading, energy forecasting, and many more.

Consider the situation when we have a complicated task or problem involving a large amount of data with lots of variables but with no existing formula or equation. ML is part of a new employment dynamic, creating jobs that center around analytical work augmented by AI.

ML provides smart alternatives to analyzing vast volumes of data. ML can produce accurate results and analysis by developing fast and efficient algorithms and data-driven models for real-time data processing.

DL is the subset of ML that, on the other hand, is the subset of AI. DL is inspired by the structure of the human’s brain. DL algorithms attempt to draw similar conclusions as humans would by continually analyzing data with a given logical structure. To achieve this, DL uses a multi-layered structure of algorithms called neural networks. Just as humans use their brains to identify the patterns and classify the different types of information, neural networks can be taught to perform the same data tasks.

Whenever humans receive new information, the brain tries to compare it with known objects. The same concept is also used by deep neural networks. By using the neural network, we can group or sort the unlabeled data based on similarities among the samples in the data. Artificial neural networks have unique capabilities that enable DL models to solve tasks that ML models can never solve.

One of the main advantages of DL lies in solving complex problems that require discovering hidden patterns in the data and/or a deep understanding of intricate relationships between a large number of interdependent variables. When there is a lack of domain understanding for feature introspection, DL techniques outshine others, as you have to worry less about feature engineering. DL shines when it comes to complex problems such as image classification, NLP, and speech recognition.

6. The Role of AI in Improving the Renewable Energy Sector

With recent movement toward decarbonization and reduction of CO₂ on the earth, demands for new and clean energy production sources drive electricity production, including energy storage for on- and off-line support of grid and electricity network. As part of clean energy producing electricity, any source of renewable energy source looks very appealing, and as we all know, one of these sources happens to be solar power for the time being.

But how can AI help in improving renewable energy supply? Moreover, how can it be integrated into the energy sector? We will discuss this matter here in this section.

Global energy demands are growing every year. And fossil fuels will not be able to fulfill our energy needs in the future. Carbon emissions from fossil fuels have already hit an all-time high in 2018 due to increased energy consumption.

On the other hand, renewable energy is emerging out as a reliable alternative to fossil fuels. It is much safer and cleaner than conventional sources. With the advancements in technology, the renewable energy sector has made significant progress in the last decade.

However, there are still a few challenges in this sector that can be addressed with the help of emerging technologies.

Technologies like AI and ML/DL can analyze the past, including historical data, optimize the present and incoming data, and predict/forecast the future. AI in the renewable energy sector can resolve most of the
challenges because we are dealing with massive incoming data from all aspects and types of renewable sources of energy, including nuclear energy as a clean source, in the form of fission presently and fusion in the near future [4].

One of the significant challenges of producing renewable energy is the unpredictability of the weather. Solar and wind are the leading sources of renewable energy, and the power generation largely depends on the weather.

Although we have efficient technologies in place for weather forecasting, there are going to be sudden changes in the climate that can affect the energy flow. The supply chain of renewable energy is prone to such vulnerabilities. Therefore, it needs to be smoothened enough to cope up with unexpected changes.

Secondly, the recent developments in energy storage technology are quite promising. But they are yet to be tested thoroughly.

The demand for renewable energy will only increase in the future. And that is why renewable energy companies should invest in ML, AI, the IoT (Internet of Things), and other emerging technologies to improve productivity and overcome the shortfalls.

Note that: The IoT is a means to connect devices and appliances to the internet. This is the technology that enables you, for example, refrigerator to order more milk, when you have a (key performance indicator) in place with some smartness of SLA (service level agreement) built into it and this, where AI, ML, and DL play the rule to do the ordering. An excellent example of such an appliance in the present market that acts as semi-supervised AI is the Alexa device of Amazon.com [4].

Even the large consumers of renewable energy, like supermarkets, factories, offices, and railways, can use AI technology to make data-driven decisions.

Now the question is how artificial energy (AI) technology, with its two other components, namely ML and DL [8] can improve the renewable energy sector.

We may be able to answer the question with the following debate.

AI is taking on many new roles in society—becoming our coworker or our partner, serving as a virtual assistant in our homes, operating our cars, and more [3].

The electric grid is one of the complex machines on earth. However, it is evolving rapidly with the addition of variable renewable energy sources.

Due to the inherent variability of wind and solar, the current grid faces many challenges in accommodating renewable energy diversity.

The utility industry needs smart systems that can help improve renewables’ integration into the existing grid and make renewable energy an equal player in the energy supply.

Here is, what we could holistically state that, how AI technology can improve the reliability of renewable energy and modernize the overall grid [4, 8].

6.1 Smart, Centralized Control Centers

The energy grid can be interconnected with devices and sensors to collect a large amount of data.

When coupled with AI, the data can give the grid operators new insights for better control operations. It offers flexibility to the energy suppliers to cleverly adjust the supply with demand.

6.2 Improved Integration of Microgrids

AI can help with the integration of microgrids and managing distributed energy. When the community-level renewable energy generation units are added to the primary grid, it becomes hard to balance the grid’s energy flow.

The AI-powered control system can play a vital role in solving the quality and congestion issues.

6.3 Improved Safety and Reliability

While the biggest goal of AI in renewable energy is to manage the intermittency, it can also offer improved safety, efficiency, and reliability.
It can help you understand the energy consumption patterns and identify the devices’ energy leakage and health.

For example, the AI-powered predictive analysis can collect the data from wind turbine sensors to monitor wear and tear. The system will monitor the overall health of the equipment and alert the operator when the maintenance is needed.

6.4 Expand the Market

The integration of AI can help renewable energy suppliers expand the marketplace by introducing new service models and encouraging higher participation.

The AI-powered systems will be able to analyze the data related to energy collection and provide insights on energy consumption.

The data would help suppliers optimize the existing services and launch new service models. It can also help retail suppliers to target new consumer markets.

6.5 Smart Grid with Intelligence Storage

The integration of AI with IES (intelligent energy storage) can provide a sustainable and reliable solution to the renewable energy industry.

This smart grid will be able to analyze a vast amount of data collected from several sensors and make timely decisions on energy allocation.

This will also help microgrids to efficiently manage the local energy needs while continuing the power exchange with the primary grid.

6.6 Cyber-Attack Prevention

The electric grid has been identified as a strategic target for the nation-state, terrorist, hacktivist, and other types of attack, and power plants remain essential elements of the electric grid. Sophisticated attacks on ICS risk equipment damage, and bring injuries to personnel, and environmental damage.

Modern network attacks begin with a piece of malware gaining a foothold on a corporate network and deceiving an employee into downloading an attachment. The malware typically tunnels a remote connection to a command and control server, and the attacker uses this remote connection to compromise select additional machines through layers of firewalls. Once deep enough into their targeted network, these attackers ultimately launch their end-game attack: either stealing information, shutting down entire plants, or even damaging equipment.

Modern, sophisticated attacks routinely defeat all software protections, including firewalls, encryption, intrusion detection systems, anti-virus systems, security update programs, and strong password management systems.

To recap, the cyber-security tool prevents smart malware from having any residence within our network, and by curling in it, smart malware has an adverse effect on our net.

7. Conclusions

Think about how access to energy affects your own life and how that translates to billions of other people worldwide. Global energy demand will continue to rise through 2040, reflecting its fundamental link to growing prosperity and better living standards for an increasing population worldwide “Energy security and environmental security are two of the most important issues the world will face in the coming decades. These are often extremely complex topics. They are also sometimes emotionally laden. There are many different perspectives on many problems involved” [9].

Some of the roles that everyone needs to consider as key trends that will play in our global energy landscape through 2040 are:

7.1 Energy Powers Modern Economies and Living Standards

By 2030, the world’s economic middle class will
likely expand from 3 billion to more than 5 billion people. This growth will coincide with vastly improved living standards, resulting in rising energy use in many developing countries as people develop modern businesses and access cars, appliances, and air-conditioned homes.

7.2 Global Energy Needs Rise about 25%, Led by Non-OECD Nations

Despite efficiency gains, global energy demand will likely increase by nearly 25%. Nearly all growth will be in non-OECD countries (e.g., China, India), where demand will likely increase about 40%, or about the same amount of energy used in America today.

7.3 Electricity Demand Nearly Doubles in Non-OECD Nations

Human activity continues to be dependent on reliable supplies of electricity. Global electricity demand will rise by 60% between 2016 and 2040, led by a near doubling of power demand in non-OECD countries.

7.4 Electricity from Solar and Wind Increases about 400%

The most rapidly expanding energy supplies will be electricity from solar and wind, together with growing about 400%. The combined share of solar and wind to global electricity supplies is likely to triple by 2040, helping the CO₂ intensity of delivered electricity to fall more than 30%.

7.5 Natural Gas Expands Role to Meet a Wide Variety of Needs

Natural gas’s abundance and versatility make it a valuable energy source to meet a wide variety of needs while also helping the world shift to less carbon-intensive sources of energy. Natural gas use is likely to increase more than any other energy source, with about half its electricity generation growth.

7.6 Oil Plays a Leading Role in Aiding Mobility and Modern Products

More electric cars and efficiency improvements in conventional engines will likely lead to a peak in liquid fuels use by the world’s light-duty vehicle fleet by 2030. However, the oil will continue to play a leading role in the world’s energy mix, with growing demand driven by commercial transportation and the chemical industry.

7.7 Decarbonization of the World’s Energy System Will Accelerate

As the world’s economy nearly doubles by 2040, energy efficiency gains and a shift to less carbon-intensive energy sources will contribute to a nearly 45% decline in the carbon intensity of global GDP. Global energy-related CO₂ emissions will likely peak by 2040 at about 10% above the 2016 level.
7.8 Nuclear Driving Electricity

Although by definition of renewable and non-renewable energy sources, NPPs are considered non-renewable type source. But being a clean source of energy that does not produce, and carbon monoxide or dioxide can be considered a renewable source of energy-producing electricity. Their new generation with a small foot-print known as SMRs may allow sitting, where a large one is unsuitable, or a cluster of small reactors could substitute for a large one.

AI along with a slew of other advanced technologies as part of its components (see Fig. 3) such as ML and DL, and ANN (artificial neural network), all together, they all have demonstrated a fantastic and huge potential to transform the energy and utility sectors.

With momentum behind the move of decarbonization, decentralization, and the rollout of novel technologies, utilities, IPPs (independent power producers), and other energy companies are employing AI to manage the imbalance in demand and supply caused by the growing share of renewable energy sources.

One of the benefits of AI and its augmentation of it in energy, either renewable or non-renewable, would be tracking all the data associated with the above roles through its sub-components of ML and DL. This way, we have a huge RoI (Return on Investment) for the money that would go into such a cyber smart system through the IoT process.

“In combination with other technologies like Big Data, cloud, and Internet of Things (IoT), AI can support the active management of electricity grids by improving the accessibility of renewable energy sources”, said Swagath Navin Manohar, Research Analyst, Energy & Environment.

With all the information behind the scene, we can use the collected sheer of data around these roles to forecast the 2040 demand level for energy to be prepared to meet such demand rather than shock us and our source of energy driving electricity.

With these data, then collecting information from them, we would be kneadable enough to be powerful enough for our appropriate and smart decision making to produce the right amount of energy at the right time to meet the demand [10].

With past decade AI has gained huge momentum and over the next decade, AI is expected to boost efficiencies across the renewable energy sector by automating operations in the solar and wind industries. It will also allow utilities and IPPs to launch new business and service models.

Information technology and applied science engineering play an essential role in society, from improving decision-making to advancing humanity’s knowledge of the world and the universe. Supercomputing, or HPC, enables scientists and engineers to push the edge of what is possible for US science and innovation. Using HPC-based modeling and simulation, they are able to study systems that otherwise would be impractical or impossible to investigate in the real world due to their complexity, size, fleeting nature, or the danger they pose.

Exascale computing will provide the capability to tackle scientific discovery and national security challenges at levels of complexity and performance that previously were out of reach.

In conclusion, the collaboration between AI/ML and DL with HPC augmentation and its partner human is essential.

Furthermore, “In addition to making the electricity system intelligent and flexible, AI algorithms help utilities and energy companies understand and optimize consumer behavior and manage energy consumption across different sectors”, noted Manohar.

“Meanwhile, complex ML algorithms combined with
real-time weather data from satellites, ground-based observation, and climate models can be used to forecast the electricity generated by Renewable Energy Source (RES) like wind, solar, and ocean”.

AI-based applications can create further revenue opportunities for the energy and utility sector by:

• Empowering software applications to analyze large data sets, identifying patterns, detecting anomalies, and making precise predictions.
• Aiding the development of smart applications that can autonomously make accurate decisions based on learning. This drives AI’s integration with a wide range of applications.
• Enabling customer-centric solutions that understand evolving customer needs and make automatic recommendations.
• Using predictive analytics to improve equipment O&M and predict downtime, which can extend the lifetime of the equipment.
• Facilitating active customer participation in demand-response programs using game theory algorithms and leveraging block chain to protect data.

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