NATURALISTA CAMPANO
ISSN: 1827-7160
Volume 28 Issue 1, 2024

Improving Solar Energy System Performance Using Artificial Intelligence (AI)

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Abstract: Artificial intelligence can be used to analyze data related to the performance of solar panels, such as temperature, solar radiation, and humidity level, and this is done by collecting this data from sensors located in solar panels and feeding it into machine learning models for analysis.
Thus, artificial intelligence can identify conditions that affect the performance of solar panels, such as pollution, dust accumulations, or structural damage, as well as provide feedback for maintenance and cleaning to maintain the maximum benefit from the generated solar energy. It can also be used to analyze data about the performance of solar panels and predict their future performance. Predictions can be made from data, artificial neural networks (ANNs) for machine learning, and long short-term memory (LSTM) networks for deep learning and used to estimate the performance of solar panels under different conditions, such as changes in solar radiation or temperature; then improve the use of solar energy and increase its efficiency. Artificial intelligence can be used in image analysis and optical inspection to evaluate the performance of solar energy systems. It can be used to analyze satellite images, determine the efficiency of solar panels, monitor the condition of solar stations, and verify any defects that may affect the performance of the systems. Deep learning DL algorithms use complex nonlinear combination functions to manipulate data.
The research included some deep learning DL techniques, such as deep convolutional neural networks (CNN), long short-term memory (LSTM), and generative adversarial networks (GAN), as deep learning is the most widely used in detecting and diagnosing defects in renewable energy. The research seeks to improve the performance of solar energy systems by linking them to artificial intelligence and activating their application in Iraqi industry.

Research problem
The industry in our country, Iraq, lacks the ability to improve renewable solar energy systems by linking them to artificial intelligence, due to the Iraqi industry and solar panel factories' lack of this technology.

The aim of the research
There are a range of diverse benefits to switching from oil to renewable energy sources (RES), including reduced costs of producing energy from renewable sources (reduction in carbon emissions), and a competitive market. Renewable energy is emerging as a reliable alternative source of energy, being safer and cleaner than traditional energy sources. Nevertheless, there are still some challenges needed to address this cutting-edge technology using artificial intelligence, because artificial intelligence evaluates the past, improves the present, and predicts the future. Therefore, artificial intelligence solves most of these problems and aims to reduce errors and achieve higher accuracy and smarter renewable energy (solar energy).

1. Introduction

The important role played by artificial intelligence technology in enhancing the amount of electricity generated by solar energy takes many forms, and promises a bright future for renewable energy, by using this technology, solar energy providers will be able to improve the efficiency, reliability and prices of their clean systems; which ultimately contributes to generating more sustainable electricity. As these technologies continually develop and become more widely used, their impact on the solar energy sector in general is expected to grow. This, in turn, promotes an increase in renewable electricity generation and helps combat climate change.
The role of artificial intelligence in enhancing solar energy generation rates has become extremely important as the world continues to shift towards renewable energy sources, and in light of growing concerns about climate change, with the need to develop sustainable energy solutions, solar energy has emerged as a major player in the energy market. Globalism.
One of the main ways in which artificial intelligence is used to enhance the amount of electricity generated by solar energy is through predictive analytics technology, by leveraging machine learning algorithms and historical data, these systems can predict solar energy production based on factors such as weather conditions, solar

brightness and temperatures,this would enable solar producers to better manage and plan solar energy production, thereby reducing waste of that renewable energy, and ensuring a more consistent electricity supply to the grid. Artificial intelligence is also being used to improve the design and placement of solar panels.
In this regard, machine-learning algorithms have the ability to analyze huge amounts of data to determine the optimal design and orientation of solar panels, taking into account factors such as geographical location, sun exposure, shade, this leads to solar installations that are more efficient at capturing sunlight and converting it into electricity. What ultimately results in an increase in the production of electricity generated by the system in general, [1].
Another important application of artificial intelligence in enhancing solar energy production is the use of drones and computer vision technology to inspect and maintain solar installations., In this regard, drones equipped with high-resolution cameras and image recognition programs operating with artificial intelligence can quickly and accurately identify defects or malfunctions in solar panels, this will help solar energy providers confront any problems that may affect the performance of their solar systems, ensuring that they continue to function as efficiently and effectively as possible.
Artificial intelligence plays a vital role in the development of smart grids; which is essential for integrating renewable energy sources such as solar energy into the existing energy infrastructure. Smart grids use artificial intelligence algorithms to analyze data from various sources, such as electricity consumption patterns, weather forecasts, with the aim of better managing the distribution of electricity and achieving a balance between supply and demand. This helps prevent power outages and ensures optimal exploitation of solar energy, which reduces dependence on fossil fuel sources and reduces greenhouse gas emissions [2].

1. Solar Energy Technologies (SET)

1.1 Concentrated solar thermal energy (CSP)

Concentrated solar power (CSP) is a form of thermal energy that may carry electricity-using sunlight, also known as electromagnetic radiation, which is light from the sun. As a result, CSP systems use only direct sunlight; the power of electromagnetic radiation is commonly known as direct normal irradiation (DNI). Mirrors provide reflection and focus solar radiation onto receivers that tend to receive the energy and convert it into heat, which can then be used to generate electricity or stored for future use. CSP is carbon-neutral, less expensive, and mostly used in large power plants, making its consumption potentially the world's future renewable energy technology for power generation, [3, 4].

1.2 Solar photovoltaic energy

The use of optimization techniques in solar PV facilities has expanded significantly.
The number of PV installations has increased according to the global electricity market in 2018. Solar PV, for example, has overtaken all other renewable energy technologies to become the fastest growing in the world since the mid-1980s. PV capacity has reached an average of 15% per year in the last few years, which has risen to over 30% and as far as 40%. Photovoltaic has evolved from a specialized laboratory into a specialized factory, and this expansion has been linked to the creation of progressively larger dedicated areas as manufacturing units. As a result, there has been significant automation of industrial processes, as well as economies of scale, [5].
A serious problem that can arise from photovoltaic systems is the degree to which amorphous silica allows “thin films” to generate power. A photovoltaic power generation system consists of several assemblies including fixtures and cells combined. Kilowatt peak (kWp) measures the electrical power that a system can provide directly from the sun at its maximum temperature [6].

2. Artificial Intelligence (AI)

Artificial intelligence (AI) refers to data processing systems and associated technical resources for human intelligence to carry out a task. AI-based systems can analyze their environment and take action autonomously. AI can also use, train, and analyze data for decision-makers in database analysis, accounting, information retrieval, product design, medicine, food quality control, biometrics, forensics, and production and distribution planning.
In environmental and renewable energy applications, AI is gaining traction due to its ability to automate systems to enhance reliability and profitability. Since renewable energy data is complex in nature, AI in power systems can help improve grid stability, reliability and dynamic performance in terms of optimization, data exploration, classification, regression and aggregation and the development can enhance system learning, control and maintenance to improve performance and quality.
This method has promoted data-driven research to investigate complex and difficult challenges in energy systems. To solve complex and ill-defined problems, some computational intelligence techniques outperform traditional

data processing techniques. Among the most effective AI techniques are: knowledge-based systems including artificial neural networks (ANN) and fuzzy logic. DL is a subsection of ML, and therefore both are AI techniques. Statistics, neural networks, and evolutionary learning are all used in artificial intelligence. The appropriate approach for a particular application depends on the nature of the problem, the accessibility of the data, and the accuracy and ease needed [7].

3. Machine Learning (ML)

Machine learning (ML) consists of strategies that allow systems to perform a task automatically from experience (data stored in a record) without human intervention, the process of implementing machine learning begins with raw data, and progresses through feature extraction, training, evaluation, and model distribution, the process often begins by identifying time series data (for example, inventory or returns data), and relevant information over a given time period to achieve a goal.
Machine learning is the best choice for problems with multiple parameters including the following: massive intelligence in data, sensing and computation across media, swarm intelligence: processing information related to group behavior, hybrid and enhanced intelligence: the integrated application of human and artificial intelligence, coordination and autonomous control: operating machines and systems automatically without human intervention, optimal decision-making: obtaining control points to maximize system efficiency without any variables, brain-inspired intelligence computation: principles and techniques for brain-inspired research, sensing, and study, big Intelligent Computation: Models and systems rely on the application of quantum computation.
The four categories of machine learning algorithms, including supervised, unsupervised, semi-supervised learning, and reinforcement learning also describe the most common methods and applicable techniques for machine learning [8].

4. Artificial Neural Network ANN

An artificial neural network (ANN) is a type of machine learning model inspired by the structure and function of the human brain, it consists of layers of interconnected nodes or artificial neurons, which receive inputs, perform mathematical calculations, and produce outputs. Neural networks consist of three main layers: the input layer and the output layer, in addition to a hidden layer or layers. These networks perform well in tasks that require finding patterns.
ANNs are used in a variety of applications, such as image recognition and more. ANNs are trained using large data sets and algorithms that adjust the strengths of connections between neurons to minimize loss between predicted and actual outputs. Once trained, ANNs can make predictions or classifications on new, unseen data. While there are many artificial intelligence algorithms these days, neural networks are capable of performing what is called deep learning. While the basic unit of the brain is a neuron, the basic building block of an artificial neural network is a sensor that performs simple signal processing. They are then connected to a macro cell network. A computer with a neural network is taught to do a task by having it analyze training examples, which are pre-labeled. A common example of the uses of neural networks using deep learning is image recognition.
Artificial neural networks consist of nodes, or what we previously mentioned as neurons or processing units, connected together to form a network of nodes. Each connection between these nodes has a set of values called weights that contribute to determining the values resulting from each processing element based on the values. Included in this element, [9].

5. Deep Learning (DL)

Deep learning DL is the symbolic neural network-based approach, which can transcend and reduce gradients. This approach can extract features from large datasets, allowing flexible modeling in network designs and model parameters. In general, DL algorithms combine and train a set of classifiers, then aggregate the predictions into a single prediction/decision. DL models consist of multiple levels or stages of nonlinear information processing, such as monitoring or unsupervised learning to extract features at progressively improved levels in increasingly more layers.
In addition, DL is an interdisciplinary field integrating studies of neural networks, artificial intelligence, pattern recognition, signal processing, graphical modeling and optimization. Increasing processing power of chips (such as general-purpose graphics processing units - GPGPUs), and increasing number of training data. Some deep learning techniques include DL such as deep convolutional neural networks (CNN), long short-term memory

(LSTM), deep belief networks, generative adversarial networks (GAN), and in this context, DL is most commonly used in detecting and diagnosing renewable energy defects, [10].

6. Convolutional Neural Networks (CNN)

CNNs are a type of DL with a network-like structure, these are NNs that replace matrix multiplication with convolution in at least one of its layers, and programs such as Python are commonly used to create DL machine CNN applications for utilities or large PV farms, as well as utility grids. It includes input and output layers with several hidden layers. CNN has a complex structure, including convolution and pooling layers in most networks. The CNN convolves the entire image as well as the intermediate layers before the output layer using various kernels in the convolutional layers. Image representation and network parameter sizes are reduced using pooling layers. Pooling computations as well as convolutional layers are language independent. Moreover, CNN includes two training techniques namely (1) forward stage and (2) backward stage. The forward step represents the input image with the existing parameters (weights and bias) while the backward step calculates the gradient for each parameter using chain rules. The gradients update all parameters, preparing them for the next calculation. Network learning can be stopped after enough forward and backward iterations, [10].

7. Long short-term memory (LSTM)

LSTM is a neural network architecture designed to process time-dependent variables in time series datasets, this type of network can use prior knowledge to predict the future state of a variable, which is useful when the input data are not independent. The recurrent neural network (RNN) of LSTM does not use an unconvolved ring cell, which allows prior information flow to the subsequent prediction step.
However, the developed model may prevent it from effectively handling long-term dependencies; for example, the learning process removes gradients during the back propagation phase. To overcome this challenge, LSTM networks use a simple three-gate architecture: input, output, and forgotten or hidden gates. This combined with the continuous scaling of the computation structure ensures overall memory retention, without specific hardware and software acceleration. The computation time of LSTM can be estimated directly proportional to the number of parameters. The LSTM structure can also be used to model solar radiation. In essence, comparing LSTM with the usual DL-based approach, LSTM network models can enhance the predictability and efficiency of the system, [10].

8. Generative Adversarial Network (GAN)

It is a type of artificial intelligence model that uses two neural networks, the generator and the discriminator, to generate new data similar to the training data. To circumvent the small sample problem, generative adversarial networks (GANs) were used.
GAN improves the discriminator and parallel generator. In this case, the generator generates samples with the most realistic distributions, while the discriminator produces the most accurate classification result. High-quality sampling and improving training stability are two common goals for adopting GAN algorithms. The main goals of many GAN-based methods are to increase performance, generate high-quality samples and improve training stability.
The structure of the generator can also be modified using the online output model or generating a Laplacian pyramid framework file. Additionally, some of the heuristics used to improve the stability of GAN training include; virtual batch normalization, feature matching and one-sided label smoothing [11].

9. The impact of artificial intelligence in the renewable energy sector

Renewable energy is considered the most prominent sector that is witnessing sustainable development and increasing interest in the world. Artificial intelligence contributes to improving the efficiency of renewable energy use. Through data related to energy production, it can analyze this data and extract valuable information from it, for example, it can be used to analyze wind and solar data and determine the best places and times to generate power through renewable energy sources.
This contributes to increasing the efficiency of using natural resources and reducing the costs associated with energy production. Artificial intelligence can help develop energy storage technologies; storing renewable energy is a major challenge. It requires storing large amounts of energy in an efficient and safe manner. Artificial intelligence can help develop predictive models to better anticipate energy demand and regulate the storage

process; in addition, it can improve battery storage technologies and control the flow of electricity. AI enhances safety and maintenance in renewable energy; when operating renewable energy systems, there is a need for continuous monitoring and maintenance; to ensure safety and prevent any malfunctions, it can be used to analyze sensor data, monitor systems performance, and detect early problems that may occur.
This contributes to reducing maintenance costs and increasing the efficiency of the systems.
Artificial intelligence can be used to analyze data, predict future energy demand, and better control the generation process. This contributes to improving the sustainability of energy systems and achieving a balance between supply and demand [12].

10. Most prominent Technologies

Many modern technologies use artificial intelligence in the renewable energy sector. Here are some examples of these techniques [21].

10.1 Big data analysis

It is used to analyze big data related to renewable energy production. Information is collected from sensors located in solar plants, wind plants and other renewable energy sources; it is used to analyze this data and modify generation, storage and distribution processes to increase efficiency and achieve the best performance.

10.2 Improving storage techniques

It is used to improve renewable energy storage technologies; Artificial intelligence can be used to analyze data related to energy consumption and future expectations of energy demand, and build predictive models to anticipate demand and better control the storage process. It can also be used to improve battery storage technologies and control the flow of electricity.

10.3 Smart networks

Smart grids use artificial intelligence to improve the management and operation of electrical networks. It is used to analyze data related to the networks, predict electrical loads, predict the occurrence of faults, and control energy distribution effectively.
This contributes to increasing the efficiency of the network and improving its sustainability.

10.4 Image analysis and optical examination

Artificial intelligence can be used in image analysis and optical inspection to evaluate the performance of renewable energy systems.
It can be used to analyze satellite images, determine the efficiency of solar panels, monitor the condition of solar stations, and verify any defects that may affect the performance of the systems.

10.5 Improving solar energy efficiency

It can be used to improve the efficiency of solar power generation. This is done by analyzing data regarding the performance of solar panels and better adjusting the power generation process.

11. Key advantages of using artificial intelligence in the renewable energy sector

There are many advantages to using artificial intelligence in the renewable energy sector, including [12].

Improving efficiency

Artificial intelligence can analyze big data related to renewable energy generation and improve the efficiency of operations. Intelligent systems can analyze patterns, predict faults and make possible improvements to increase the efficiency of power generation.

Improve planning

AI can analyze location, weather and forecast data to improve planning processes and select the best sites for renewable energy generation. It is possible to identify the places that achieve the highest rates of utilization of solar energy and determine the best strategies for distributing electricity.

Predictive maintenance
Artificial intelligence can analyze data to detect any problems occurring in renewable energy plants early and provide accurate predictions about necessary maintenance. Parts that need replacement or maintenance can be identified before major failures occur; this helps avoid unplanned downtime and reduce costs. By using artificial intelligence in the renewable energy sector, significant improvements can be achieved in generation efficiency, planning, maintenance and integration. It can also reduce costs and increase the sustainability of renewable energy in general.

Developing new materials for solar panels:
Current technologies for producing solar panels require the use of rare materials and high temperatures. Artificial intelligence can help speed up testing of suitable materials for use in new solar panels without the need for high temperatures or the use of rare elements. Experiments can be performed and analyzed automatically, saving time and effort and providing environmentally better materials, and artificial intelligence can help develop solar panel recycling technologies and reduce their environmental impact.

12. Linking artificial intelligence with solar PV systems

Artificial neural networks (ANN) are one of the most popular methods for solar radiation prediction and have been successfully used for solar radiation prediction and solar system design. Our main contribution in this research involves focusing on artificial neural networks in solar energy systems, because they are able to sort data, detect patterns, and solve estimates of nonlinear functions. To increase processing speed, artificial neural networks, due to their large-scale nature, are used to predict in high-dimensional spaces, where nonlinear functions between quantities of different sizes are more likely to exist.
However, the flexibility of artificial neural networks to accommodate changes in the distribution function increases the risk of "overfitting," i.e. significantly overfitting the training data. It has also become clear that weather classification has played an important role in the development of a number of new AI-based models, including models based on convolutional neural networks (CNN) and generative adversarial networks (GAN) for predicting power generation. To produce solar energy, many techniques have been invented based on artificial intelligence, using recurrent neural network (RNN), long short-term memory (LSTM) networks, and convolutional neural networks (CNN). Both convolutional neural networks (CNNs) and recurrent neural networks (RNNs) are powerful AI tools, but although CNNs can retrieve information in many spatial dimensions, however, an RNN can only learn one, and solar power generation requires knowledge of both.
Therefore, for accurate solar energy prediction, it is necessary to have a method that can extract spatial and temporal features. There is now an opportunity to apply data-driven algorithms to enhance solar forecasting because of the availability of data in previously unimaginable detail.
These factors (temperature, sunlight, humidity, and dust) determine the output power produced by a PV system. Each of these parameters changes with time and the importance of the problem.
The open circuit voltage and short circuit current of a photovoltaic cell are the most important ones that should be examined to prove the variation in the power supply produced by the cell.
An increase in ambient temperature causes a decrease in the voltage of the open circuit, as well as a slight increase in the short-circuit current, which leads to a decrease in efficiency.
Effect of temperature on the operation of solar cells High temperatures lead to higher reverse saturation current and lower VOCs, causing a decrease in the fill factor, and thus a decrease in the capacity of the solar cells.
Artificial intelligence is used to implement the design of prediction, control, optimization, maintenance and cyber security networks of the energy system.
This indicates that the effective development of artificial intelligence is a promising and sustainable strategy to mitigate the carbon footprint [13].

13. Conclusions

By using advanced artificial intelligence technology in the renewable energy sector, we find that there is great potential to improve the efficiency and sustainability of renewable energy. Where artificial intelligence can:
1. Analyzing data and achieving continuous improvements in the performance of solar and wind power plants. It can also be used for predictive maintenance and saving costs and time.
2. Improving energy storage systems by reading and analyzing a huge volume of data at a low time and cost in order to obtain a predictive result for potential outages, maintenance, and increasing the life of batteries.

3. Artificial intelligence، through its ability to predict، reduces operational costs and increases productivity and lifespan of systems.
4. Artificial intelligence works through a group of electrical، electromechanical، chemical and thermal systems to detect faults that are expected to occur.
This is done by collecting data using sensors and sensors and then comparing it with data in databases in the past, thus determining the set of conditions that typically lead to failure or malfunction of a particular component. All of this reflects positively on the system by reducing downtime, improving the operational life of storage systems, and increasing profits.

Recommendations
The aspect that must be addressed is dust, which blocks part of the sunlight and reduces the performance of the photovoltaic system. It is necessary to schedule maintenance and a cleaning routine for photovoltaic facilities as mitigation measures to maximize the performance of the photovoltaic system.
There are future proposals by the researcher to enhance the operation of the solar system, such as anti-reflective coatings for cell uses and the integration of plasma or insulating nanostructures installed on different cell layers.

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