Applications of AI and IoT in Renewable Energy

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Abstract

Huge energy utilization is going on the planet as electrical energy and as mechanical energy. Electrical energy is utilized all over the place and it has a significant offer in the advancement of the world. Solar and wind are the primary energy sources and that additionally relies upon climate conditions. Energy stockpiling innovation is very encouraging and it must be tried altogether. The interest for renewable energy will increment later on so there is a need to put resources into IoT and AI innovation. To beat the electrical energy lack, the option is renewable energy. Renewable energy sources gathered by utilizing the sensor. Internet-of-Things (IoT) and Artificial Intelligence (AI) are the innovations that are useful for age of the electrical energy for home devices and mechanical regions. IoT and AI have different applications in Renewable Energy age. IoT utilizes different kinds of sensors like piezoelectric sensors that convert human body warmth to the electric converter, Solar boards are utilized to produce electrical energy, and solar boards are associated with the power storage circuits. IoT is utilized for automation to improve production by automating the control, grid management, observing an enormous no of points in distributed systems, and producing green energy for residents. Computer based intelligence is utilized in the electrical grid, the electrical grid is a complex machine, and AI innovation can improve the dependability of renewable energy and modernize the general grid. Computer based intelligence can be utilized in smart brought together control habitats, to improve microgrids coordination, to improve security and dependability, to grow the market, and astute stockpiling in smart grids. In this paper, we are researching the different utilizations of IoT and AI in renewable systems.

Keywords: Renewable Energy, Smart Grid, Electrical Energy, Artificial Intelligence, Internet of Things, Renewable Energy Resources

Abbreviations

AI- Artificial Intelligence

ANN- Artificial Neural Network

IoT- Internet of Things

NNW- Neural Network

ES- Expert System

FL- Fuzzy Logic

EC- Evolutionary Computation

SVN- Support Vector Machines

MPPT-Maximum Power Point Tracking

FOFLC - Fractional Order Fuzzy Logic

PLC- Power Line Control

RFID- Radio Frequency Identification

P&O- Perturbation and Observation.

RL- Reinforcement Learning

ARIMA- Autoregressive Integrated Moving Average

WNN- Wavelet Neural Network

DBN-Dynamic Bayes Network

PSO- Swarm Optimization

MAPE- Minimum Mean Absolute Percentage Error

LSTM-Long Short-Term Memory

APF-Shunt Active Power Filter

RBF- Radial Basis Function

STLF- Short Term Load Forecasting

MTLF- Mid Term Load Forecasting

LTLF- Short Term Load Forecasting

RVFL- Random Vector Functional Link

I. Introduction

Day by day use of energy is in demand. There are conventional energy sources like Natural gases, fossil fuels and oil are available, however, the use of these conventional energy sources is having some problems like ozone depletion, acid rain, greenhouse effect, etc. These conventional energy resources are harming the environment due to which there is a need for Energy resources that are free from pollution. To keep the environment pollution clean and green the solution is to employ Renewable energy resources like Geothermal, Hydel power, Wind power, photo voltaic generation, biomass, etc. [1-4]

Sporadic is the major problem in renewable energy. Apart from this, Variation in continuous power fluctuation, load demand, the power outage is also problems in renewable energy. On the other hand, the production of excess renewable energy also results in wastage of energy [5-9].

IoT and AI are the technologies that are addressing the issues in the renewable energy sector. In IoT, the system components like hardware and software are connected through the internet. In IoT, each object in the system is communicating with the related object using the two-way communication system. Considering the energy System, IoT can form a single system by providing advanced connectivity of heterogeneous objects. However, few challenges are there in the whole integration of the various domains when numerous services are bound to accessible beyond machine to machine communications. When the number of systems like communication system, control system, and power systems is integrated then the situation becomes worst. So, integration of the subsystem is a blistering research topic for the researchers [10-12].

Artificial intelligence means mimicking human intelligence. Humans have a natural brain for thinking and taking the decision. the classification of a is done in school category that is ANN/NNW, ES, FL, and EC. Artificial intelligence is almost similar to neural network applications. Artificial intelligence is a collection of various methods. This machine is learning by using the available data and based on that it builds a capable system autonomously. AI methods used in the smart grid may be divided into an expert systems, supervised learning, unsupervised learning, reinforcement learning, and ensemble methods. In the ES system a human expert in the loop approach, which is utilized to solve specific issues. Supervised learning is a type of AI where the mapping of input and output is examined to anticipate the outcomes of fresh inputs. Unsupervised learning comes under machine learning where unlabelled data is utilised to gather information. Reinforcement learning is differed from supervised and unsupervised methods due to its intelligent agent method. RL tries to maximise the idea of increasing recompence. The ensemble methods are the combination of various AI algorithms that helps to overcome a single algorithm's limitation and tries to increase the overall performance.

2. Internet of Things

IoT consists of various networks implanted devices interconnection that is used in day-to-day life and is integrated into the internet. The goal of IoT is to automating various domain operations like health care systems, surveillance systems, security systems, industrial systems, and so on. The fully automated process can be accomplished only when the devices in the various domain contain transceivers, microcontrollers, and protocols. There are three layers in the IoT system named perception, network, and application layer. The perception layer is having internet-enabled devices. These devices percept and detects the object followed by collects systems information and then using the communication network the information exchange took place. The devices in the perception network are cameras, GPS, RFID's, etc. The next layer is the network layer that forwards the data from PL to AL. Here, IoT needs Internet and short-range networks like Bluetooth and Zigbee to transmit data from perception networks to short-distance gateways. The information is carried to long distances using the 2G,3G,4G, and PLC. In the application layer, the incoming information processing takes place to make understandings, and based on this power distribution and management strategies are designed [13-15]. The IoT layer is depicted in figure 1.

Application Layer **(Smart Homes, Smart Cities, Electrical Vehicles, Fault Detection, Renewable Energy Sources, Power Lines, Demad Profiling, Demand Response etc.**
Network Layer **(Gateways, Zigbees and Bluetooth, Wi-Fi, 2G,3G,4G, PLC etc.)**
Perception Layer **(Wireless Sensors, RFID's, Camera)**

Figure 1: IoT Layers

It is expected that by 2025, globally 75 billion gadgets g are anticipated to be Internet-connected, giving consumers, manufacturers, and utility providers a plethora of data (Statista, 2018). The growth of IoT coincides with the emergence of artificial intelligence, which is driven by big data and offers the granular information required to feed machine learning algorithms.

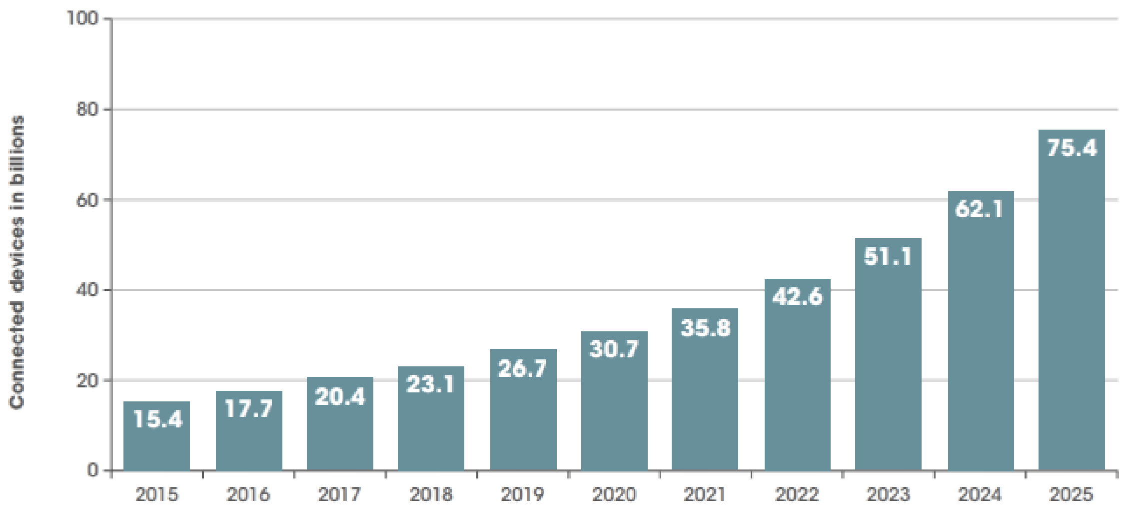

Figure 2: The globally connected IoT devices from 2015 to 2025 (Source: Statista 2018)

2.1. Applications of IoT

The adoption of renewable energy sources may be boosted even further by utilizing cutting-edge disruptive technology. The incorporation of IoT in the renewable energy segment is greatly facilitating its growth. Internet of Things applications addresses several issues that are impeding the uptake of renewables.

Monitoring the Power lines Online

The power systems have covered many buildings and areas. The power outage is the issue that is reducing the reliability of the system [16]. Reliability is harming public health and the economic system. Integration of the IoT with the power grid helps to improve the reliability of the Power Grid. This is achieved by monitoring the transmission line status continuously Moreover; it is also sending the environmental behavior and Consumer's activities reports to the grid control unit so. the control unit extracts the information from the reports and then process the processor that to detect the faults, isolate the falls and then try to resolve the fa and then try to resolve the faults intellectually. It is necessary to consider the location in the case of blackouts when you perform the energy Restoration in smart grids. For instance, providing high reliability for health and industrial systems is dangerous. the Restoration problem is complex, as there are various combinations of switching operations, are involved and this exponentially increases when the system components are increased. When a smart grid is designed in a hierarchical model divides the problem into multiple units for restoring the power within the region. this helps to improve the data processing time and speed up Restoration process. if any case any of the control unit is not able to restore the energy in a particular region, then this problem is reported to the upper levels for or proper actions and the higher levels are having a large system view [17-19].

Smart homes and cities

Smart home is expected smart grid application in IoT. Smart homes incorporate smart TVs, home security systems, fire detection, lighting control, monitoring temperature etc. Which systems and appliances have sensors and actuators that are responsible for monitoring the environment and for sending the surveillance data to the home control unit. The control unit allows the house owners continuous monitoring and full control of electrical appliances. the surveillance data is used for predicting the future activities and to provide secure, comfortable and efficient living environment. In order to form smart community a group of smart homes in neighbourhood are connected to each other via neighbour area network (NAN). It helps keep smart community to share the results of the outdoor surveillance camera for detecting accidents, robberies and also helps to inform police. The smart community concept is also used in supporting the social networking, health and for managing the shared resources. It is also used to build smart cities where they can develop a full surveillance system for monitoring various activities within the whole city [20][21].

Energy management and demand side

Managing the energy at demand side means doing modifications in customers energy consumption profile based on varying electricity prices over the time and other payments enticements from utility companies. Demand response is useful for minimising the electricity bills of customers, shifting peaks load demand, reduce Power Grid operation cost, and reduce energy loss and greenhouse gas emissions. IoT components are responsible for collecting the energy requirements from various home appliances and then sending that information to the smart metres. The control unit is responsible for scheduling home appliances energy conservation based on the user's preferences in strategy that reduces the electricity bill. The demand side problems are solved at various levels of the hierarchical smart grid infrastructure. It can either salt at the level of compromises for preserving the consumer privacy law at higher levels for or creating more effective scheduling plan that will be beneficial for consumers as well as the utility companies [22-28].

Electrical vehicle integration

when the electrical vehicles are idle then they are used as the energy storage device. The benefit of using electric vehicle is they offer effective and clean transportation services. In order to reduce the emission, shear peak load and to increase the use percentage of producer renewables it is necessary to develop efficient scheduling techniques to charge and discharge electrical vehicles. The perception devices are responsible for collecting information related to the electrical vehicles like identity of the vehicle, location and battery state etc.it helps to increase the efficiency of charging and discharging the scheduling algorithms [29-31].

Distributed energy resources integration

In the power grid the renewable energy generated are integrated due to the environmental reasons like changes in the climate and its low cost. It helps to reduce greenhouse gas emission which is responsible for rising the earth's temperature. Presently meaning or meant organisation and the individuals have installed solar cells and wind turbines to obtain the power. It is necessary that renewable energy should be available so to achieve this there is need of improvement in storage Technology. The real time weather information is gathered by using wireless sensors for predicting the availability of energy in the near future. Prediction accuracy power amount is important for scheduling the energy models. Various Strategies and Optimisation methods are developed by the researchers for efficiently managing the renewable energy resources in the smart grid [19][32][33].

3. Artificial Intelligence

Artificial intelligence techniques, expert systems, and ANN have ushered in a new arena in power engineering & power electronics, presenting several opportunities to overcome these issues. AI is the replication of human intelligence in computers, with the capacity to learn from experience and make decisions based on that experience. These procedures provide main mechanisms for smart grid estimates and renewable energy system simulation, design, control, and fault diagnostics. In the renewable energy field artificial intelligence is used for forecasting the solar radiations, Wind speed data to get maximum power from the resources. These methods are helping in reducing the risk of severe with complete system and ensure the reliability [34-42].

3.1. Applications of AI in renewable energy system

Forecasting PV

In PV System solar radiation is the key factor for generating the power. In estimating the PV system accurate prediction of the Solar irradiance Is very important. so, it is important to take into account this factor at the design phase to avoid mismatch between generation of the power, storage and demand. There are two units in machine learning for forecasting Applied Modelling and real-time forecasting. In the offline modelling to train the model historical data is used and in real time forecasting current data is used for the estimation of requisite parameters.

Different methods are used for forecasting in a PV system and these methods are ANN, autoregressive integrated moving average, fuzzy logic, Support vector machine, Multivariate regression etc.

There are direct and indirect forecasting methods. indirect forecasting instantaneous power production is mapped using related data. ANN, support vector machine and multivariate regression are the direct forecasting methods. In the indirect forecasting method firstly prediction of 16 in radians intensity is done after that instantaneous power is determined.

A neural network has advantages over a typical classical model. There is no internal parameter involved in the neural network and its processing requirements are fewer. It also offers compact resolution for multiple variable problems. A neural network is capable of learning relatively complicated nonlinear relationships, making it well suited for real-world applications.[43]

PV forecasting is performed by using various neural network approaches; the convoluted neural network is one of them. CNN has different key concepts like one-dimensional convolution, pooling layers, and drop or Technology. The seven techniques are also used to forecast the weather as well as for image classification. As compared to conventional neural networks the CNN requires less features as it is having a sharing mechanism. CNN also solves the overfitting problem which is happening when the model learns details and noise in the data and it will have a negative impact on the system performance. CNN uses the pulling Concept for reducing the number of features at the time of retaining the important features; due to this it results in increased computational speed. The polling issue that is related to down sampling is also addressed.[44]

If the overfitting problem is serious at the time of training, then by using the dropout technology it can be solved and it makes the model more reliable.

There are three steps in the solar radiation forecasting system. Initially the Solar radiation input is cleaned, filtered, and validated. The next step is pre-processing the data and splitting the data into training and testing data set. The training of solar forecasting model is done by using the training data which is having different weights and these weights are modified with the help of a backpropagation algorithm. After training the model testing data is given to the Solar training model for receiving the forecast results and to test its validity. Performance evaluation of the solar forecasting model is done by comparing the results obtained with testing data. Simple perceptron is one more method which forecasts solar irradiance. Simple perceptron is a supervised learning method where the weights are modified based on the generation of undesired response at output. MADLINE’s is also used for solar forecasting [45][46]

Wind forecasting

Winsupply is stochastic in nature and due to this as compared to thermal generation systems, power generation from wind energy systems is different. Wind forecasting generation systems includes management of wind power generation, power system demand, challenges of balancing the mismatch between both. The neural network is the most frequent method used for forecasting the wind as it is a persistent stranded multilayer perceptron. Wind forecasting speed in the short term can be done by using a common type of neural network that has a multilayer perceptron. Recurrent neural networks [47] are also used for wind forecasting. The simultaneous RNN modelled with particle Swarm optimizer provides better performance. A hybrid approach which combines two artificial intelligence methods is also developed for wind forecasting. It combines ANN and FL and combinedly it is known as adaptive neural Fuzzy system model [74]. when it is difficult to determine the system parameters and to develop exact model then Fuzzy Logic model is used. Fuzzy Logic based models are also used for wind speed forecasting and generation of power at wind Park. genetic algorithm best learning is used to frame these models. by using this model, the short-term forecasting is improved in the range of minutes to hours. The drawback of these models is the computation time required is more and one has to employ a large number of Fuzzy rule bases. Bayesian methods were also developed for wind speed forecasting.

Maximum power point tracking (MPPT)

Maximum power point tracking incorporates control systems. The control systems have suitable algorithms and their systems are then used for generating optimal duty cycles. this duty cycle is given to Power DC-DC converter. it is then used to extract maximum power from the PV array. there are various challenges in designing the optimal MPPT method for PV system. the challenges are efficiency, overall cost, energy loss, and issues related to implementing and designing a particular issue. various MPPT methods are implemented for PV systems such as incremental conductance, hill climbing, perturbation and observation etc. Fuzzy logic is also used as it is in excellent characteristics in terms of speed response and it provides low oscillation at maximum power point. however, it is having drift issues as there is modification in irradiance data [48-51].

In ANN based MPPT Method in PV system then two parameters are short circuit currents, output current, terminal voltage, open circuit voltage, and the environmental factors like amount of solar irradiance, temperature of model, incidence on model and speed of wind. these parameters are nothing but the features and these are given to the input layer of neural network and it passes through the hidden layer and output layer will get the output that is estimation of the duty cycle of DC -DC Converter to track maximum power point. At the time of training neuron weights are adjusted to map output from input. The number of input variables and notes are dependent on the system complexity, availability of the data, and processing requirement. The accuracy and capability of the maximum power point tracking system using the neural network is based on the implementation and design of the algorithm at the hidden layer. The feed forward backpropagation algorithm is used in many ANN based MPPT controller to train the model. Here the information is transmitted in both the direction that is forward and backward to modify the weight link. Various input states are fed to the hidden layer with varied degrees of weights and lastly the results are given to the output layer. The back propagation network can also be used to train gradient Descent algorithms to modify the weights between each layer and minimise Tera between actual output and predicted output of ANN model [52-55] .

In Solar based PV systems, it has been observed that the Fuzzy Logic based perturbation and observed MPPT system performed excellently. DC-DC converter is used to distribute the produced power by PV system to the Load. The PV panels measured values of current and voltage are given to the Fuzzy Logic based MPPT control system to track maximum power point. The Fuzzy Logic Control Systems discover the size of the voltage change needed to match maximum power in accordance with current and voltage measured from the PV panel.

The puzzle logic P&O MPPT system regulate the duty cycle of DC-DC converter and estimates new operating voltage for PV Panel.

The heart of Fuzzy Logic MPPT controller is inference rules [56]. these rules are evaluated by using the trial-and-error process. power change hand power change w.r.t. voltage are the inputs and Fuzzy logic is design with the rule set to get perturb voltage. The key advantage of Fuzzy Logic based MPPT is it does not need the assessment of complete knowledge of the PV module parameters and correct modelling of system e complicated nonlinear connection; hence, it is well suited for real-world application [57]. Fractional order fuzzy logic [58]is implemented for controlling, accelerating MPPT, and to avoid deviation from maximum power point.

Load Forecasting

The scheduling and the operation of smart grid is uncertain and it is increasing and becoming as a challenge. The Load forecasting keeps the power system smart and stable so, however it is critical to plan and perform operations in modern power systems. Accurate forecasting helps to reduce the cost of the production and to save the electricity [59]. STLF is used to predict the load from minutes to hours, MTLF is used to predict the load from hours to week and LTLE is used to predict years load. The load forecasting is affected by the weather, historical load, demographic data, and local economy.

A hybrid approach [60] is used in STLF. This hybrid approach incorporates discrete wavelength transform, RVFL network, and empirical mode decomposition. The efficiency and accuracy are improved by using the ensemble method. The ensemble method [61] Uses the combination of 3 networks where the experimental results have

shown the model's effectiveness for STLF. There is a need of validation for the choice of the best methods in the ensemble approach. The method pooling based RNN [62] is used for STLF to address the issue of overfitting. It is done by increasing the data volume and diversity. Another and simple method [63] are used which combines multiple DNN models. There are different number of hidden layers are used to achieve the better performance. the better performance is achieved by eliminating the poor performance models. To predict the hourly load DBN embedded with parametric copula model was introduced in Texas. the results are compared with the neural network, ELM, and SVR to find out the effectiveness of the algorithm. Hybrid clustering method Based on ANN and WNN [64] gives high performance as compare to the clustering methods.

A dynamic Bayes network [65] based MTLF model is implemented to forecast the peak power load for the next year. In [66], a DNN model with an optimized training algorithm that includes two search algorithms for MTLF in power systems and offered the efficiency of the model. A neural network-based model [67] with PSO is implemented to show the feasibility and validity of the model. The improved a support vector regression model [68] for MTLF is implemented with an average MAPE of 3.60. A hybrid DL model [69] for MTLF that combines exponential smoothing, progressive LSTM, and the ensemble method. This method is competitive method used in ensemble approach.

The MARS method is [70] is implemented for LTLF. It uses ANN and LR models for predicting the relationship in load demand and numerous environmental variables. This method gives the stable results. A novel hybrid fuzzy-neuro model [71] employed for LTLF. LSTM is also well used in the domain. A LSTM-based RNN [72] model was introduced for the long-term dependencies in the electric load time series for LTLF. This method has given a promising performance. A LTLF model with hourly granularity [73] implemented using the LSTM network for solving the vanishing and exploding gradient problems of LSTM.

Table 1. Shows the summary of the approached used in renewable energy field for various applications.

Table 1. AI Application in Renewable Energy

Reference Papers	Application	Methods
[43]	PV forecasting	CNN
[44]	PV forecasting	CNN
[45]	PV forecasting	MADLINE
[47]	Wind Forecasting	RNN
[74]	Wind Forecasting	ANN, FN
[49]	MPPT	P&O
[50]	MPPT	Incremental Conductance
[51]	MPPT	Hill climbing
[53][54][55]	MPPT	ANN and Backpropagation algorithm
[57]	MPPT	Fuzzy logic
[58]	MPPT	FOFLC
[60]	STLF	DWT, RVFL
[61]	STLF	Ensemble method
[62]	STLF	RNN
[63]	STLF	DBN
[64]	STLF	ANN, WNN
[65]	MTLF	Bayes Network
[66]	MTLF	DNN
[67]	MTLF	NNW
[68]	MTLF	Support Vector Regression
[69]	MTLF	Hybrid DL model: LSTM, ensemble method

[70]	LTLF	ANN& LR
[71]	LTLF	Hybrid Fuzzy neuro model
[72]	LTLF	RNN, LSTM
[73]	LTLF	LSTM

Conclusion

Huge energy utilization is going on the planet as electrical energy and as mechanical energy. Electrical energy is utilized all over the place and it has a significant offer in the advancement of the world. IoT and AI have different applications in Renewable Energy age. IOT is network of various interconnected devices and it has the applications in renewable energy like monitoring the power lines online, smart homes and cities, energy management and demand side, electrical vehicle integration, distributed energy resources integration. Artificial intelligence means mimicking the human intelligence. Humans have a natural brain for thinking and taking the decision. the classification of a is done in school category that is ANN/NNW, ES, FL, and EC. AI is used for forecasting the PV, load, wind, and MPPT. Apart from this it has other applications as well. AI has used various approaches like CNN,RNN,DL,ANN etc for forecasting .

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