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The Impact of Artificial Neural Network (ANN) on the Solar Energy Cells: A Review

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Abstract: The proportion of energy produced by variable renewable energy sources (VRE) is growing in importance in the power industry. The high integration costs of various energy sources provide a significant barrier to widespread adoption. Due to the increasing complexity and data generating potential of the future smart grid, artificial intelligence (AI) solutions and data-intensive technologies are currently deployed in many stages of the electrical value chain and have the potential to significantly increase the system's value. When it comes to the energy industry, however, the willingness of decision makers to invest in AI and data demanding technology is sometimes hampered by various ambiguities or lack of knowledge about its effect. Previous work has indicated several applications for AI solutions in the power industry; the aim of this paper is to add to the comprehension of the significance of AI strategies in solar energy cells.

Keywords: Artificial Intelligence (AI), Solar Energy, Artificial Neural Network (ANN). Solar Photovoltaic Cells

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1. Introduction

The United States currently relies heavily on coal, oil, and natural gas for its energy. Fossil fuels are nonrenewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. Every year human activity dumps roughly 8 billion metric tons of carbon into the atmosphere, 6.5 billion tons from fossil fuels and 1.5 billion from deforestation [1]

The huge consumption of fossil fuels has caused visible damage to the environment in various forms. It creates lot of environment problem and finally our ecological cycle will be affected. The energy industry needs to get more from existing fields while continuing to search for new resources. Due to technological advancement vehicles are made with improved fuel efficiency and also perfect hybrid vehicle are made. Also the improvements are needed so that wind, solar and hydrogen can be playing more valuable sources in the energy field. The many types of renewable energy resources-such as wind and solar energy-are constantly replenished and will never run out that is one benefit .Most renewable energy comes either directly or indirectly from the sun. Sunlight, or solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses. The another advantage using renewable resources is that they are distributed over a wide geographical area, ensuring that developing regions have access to electricity generation at a stable cost for the long-term future. The sun's heat also drives the winds, whose energy, is captured with wind turbines. Then, the winds and the sun's heat cause water to evaporate. When this water vapor turns into rain or snow and flows downhill into rivers or streams, its energy can be captured using hydroelectric power. Along with the rain and snow, sunlight causes plants to grow. [1]

The organic matter that makes up those plants is known as biomass. Biomass can be used to produce electricity, transportation fuels, or chemicals. The use of biomass for any of these purposes is called bio energy. Hydrogen also can be found in many organic compounds, as well as water. It's the most abundant element on the Earth. But it doesn't occur naturally as a gas. It's always combined with other elements, such as with oxygen to make water. Once separated from another element, hydrogen can be burned as a fuel or converted into electricity. Not all renewable energy resources come from the sun. Geothermal energy taps the Earth's internal heat for a variety of uses, including electric power production, and the heating and cooling of buildings. And the energy of the ocean's tides come from the gravitational pull of the moon and the sun upon the Earth. In fact, ocean energy comes from a number of sources. In addition to tidal energy, there's the energy of the ocean's waves, which are driven by both the tides and the winds. The sun also warms the surface of the ocean more than the ocean depths, creating a temperature difference that can be used as an energy source. All these forms of ocean energy can be used to produce electricity [2].

2. The Benefits of Renewable Energy

Environmental Benefits Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies. B. Energy for Our Children's Children (Sustainability) Renewable energy will not run out. Ever, other sources of energy are finite and will some day be depleted. C. Jobs and the Economy Most renewable energy investments are spent on materials and workmanship to build and maintain the facilities, rather than on costly energy imports. Renewable energy investments are usually spent within the United States, frequently in the same state, and often in the same town. This means your energy dollars stay home to create jobs and fuel local economies, rather than going overseas. Meanwhile, renewable energy technologies developed and built in the United States are being sold overseas, providing a boost to the U.S. trade deficit. D. Energy Security After the oil supply disruptions of the early 1970s, our nation has increased its dependence on foreign oil supplies instead of decreasing it. This increased dependence impacts more than just our national energy policy [3].

3. Existing Available Renewable Resources in Iraq

In limited available technology and economical consideration to trap and store the renewable energies when we are in abundant supply in the area where other have to concentrate much. The production of fuel increases. That alternative energy sources in Iraq is limited use and production .The reason is the presence of oil and the lack of Journal of Clean Energy Technologies, Vol. 2, No. 1, January 2014 environmental awareness. And a few investment in the field of renewable energy. The types of renewable energy in Iraq are hydropower dams and reservoirs (LIMITED) .Solar energy for street lighting aad wind power projects under implementation, but in limited locations depending on the potential availability of wind and these sites on the west side, the south-west and north-west of the country and near the coastal areas (specific space in Iraq in the southern city of Basra) [4].

4. Solar Energy

Solar energy is an abundant form of RE source that comes from solar radiation. It broadly categorizes based on yielding; they are active solar and passive solar techniques. An active solar technique comprises of solar water heating and PV systems. Passive solar techniques include orienting a building to the sun, choosing materials with sympathetic thermal mass or light-dispersing chattels, and designing spaces that circulate air. Nearly 174PW (petawatts) solar energy hits the earth's atmosphere, whereas 30% reflected space while land masses and clouds absorb the remaining 70%. Generally, the world's population lives in areas with insolation of 3.5–7.0 kWh/m² per day. Therefore, effectively managing this RE is a challenging task.[5]

4.1 Application of Solar Energy

As discussed earlier the abundant resourceful energy having various applications are listed below. [6]

- *Solar water heating:* It is a process of utilizing solar energy in the form of heat with the aid of solar thermal collectors. In general, solar water heaters used in industrial and residential applications serve different environments. A couple of (active and passive) methodologies are used in solar water heater by heating fluid via a

storage system. This system utilizes water or working fluid, perhaps both in some cases and heat directly or through a light concentration mirror.

- *Solar heating in buildings:* Solar heating & cooling technologies gather the thermal energy from solar and utilize its heat to endow with hot water, space heating, cooling, and pool heating for residential, commercial, and industrial applications. It certainly reduces fuel consumption in different climatic conditions. Solar distillation: It is a process of evaporating the saltwater and collects the freshwater from the condensation, which is called desalination. This process implies different configurations but relies on the simple process in which an influent solution comes into the system, and the supplementary volatile solvents depart in the effluent, leaving the salty solute. It fully relies on solar energy.
- *Solar pumping:* Unlike other pumps, solar pumps rely on power generated from solar PV panels, having a less environmental impact. These pumps are more economical, primarily due to the lower operation and maintenance costs than the pumps powered by an internal combustion engine.
- *Solar furnaces:* A solar furnace is mostly utilized in industries for their large utility by concentrated solar power to generate high temperatures. This methodology includes parabolic mirrors on to focal point to reach 3500°C for melting steel generating electricity and so on.
- *Solar cooking:* Solar cooking is a device that relies directly on sunlight to heat water and to prepare food. Most of the presently utilized solar cookers are inexpensive, low-tech devices. At the same time, a few are as expensive as conventional stoves, and sophisticated large-scale solar cookers could cook for several people. Since they do not consume any fuels or operation cost, this leads pollution-free and trim down the deforestation and desertification while gathering firewood for cooking.
- *Solar electric power generation:* Solar power generation plays a vital role in all forms of REs with its abundant source of availability, inexhaustible, and eco-friendly nature. In solar power generation, the PV cells absorb photons in the sunlight and generate it in the form of Direct Current (DC). The sun liberates nearly 42 trillion kilocalories of energies to the earth every single second. If these energies are utilized optimally for an hour, then it might be adequate to satisfy a year's power demand for the entire planet. These aforementioned significant causes led the researcher to put forth the research vision towards developing solar PV power generation.
- *Solar thermal power production:* Solar thermal power production utilizes concentrated sunlight to produce high temperature for electricity generation. There are two significant components, reflector and receiver that handle the sunlight effectively—the steam produced by circulating the heat transfer fluid into the receiver in most types of systems. The steam further utilized to run a turbine as a mechanical rotation to generate electricity. There are different types of solar thermal power production, namely linear concentrating systems, solar power towers, and solar dish systems.

4.2 Solar Photovoltaic Cells

Solar PV cell converts light energy into electrical energy due to the photovoltaic effect. When sunlight hits the semiconductor material, the photons in the rays trigger the electrons to flow freely in the circuit, thus generating electricity. Generally, PV cells fabricate with silicon to generate electricity efficiently. In a solid crystal, every silicon atom distributes each of its four valence electrons with another adjacent silicon atom. It consequently forms a covalent bond connecting them as a tetrahedral lattice structure. Whereas, conditions like time, temperature, humidity, solar irradiation, and even wind speed directly influence the solar PV cell model, power generation. The factors like dust, partial shading, and aging also interrupt the power generation.[5]

4.3 Principles of Solar Photovoltaic Cells

Solar PV cells are a semiconductor device utilized to generate electricity; they configure with p-type and n-type semiconductors. The p-type, with one less electron, draws the leftover electron from the n-type to stabilize itself. When solar energy hits a PV cell, the photons in the sunlight triggers the electrons in the semiconductors, which flow freely to generate electricity, and it is said to be a photovoltaic effect.[5]

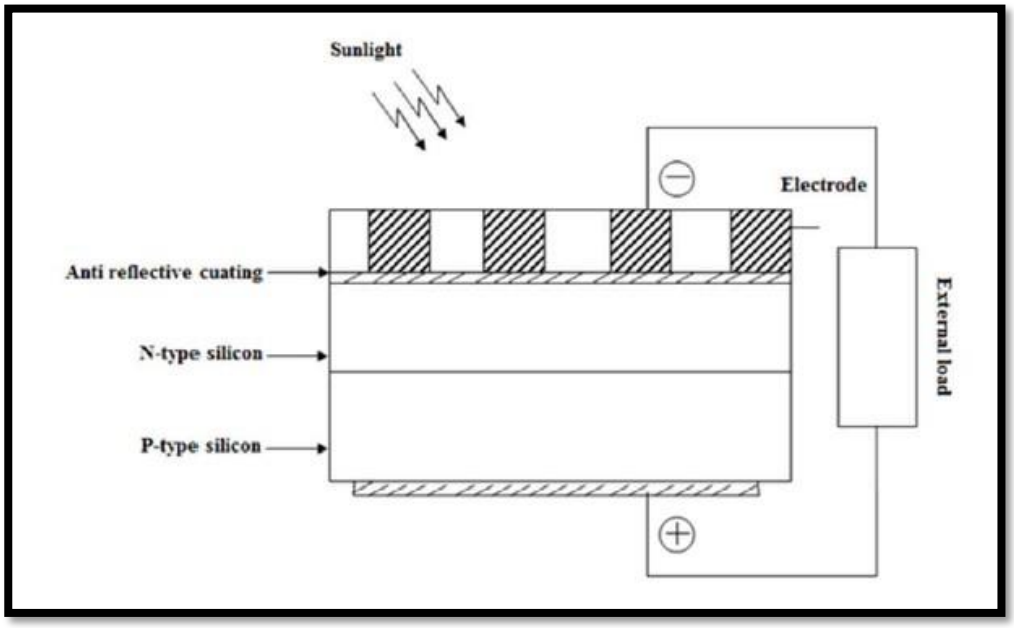

Figure 1 Circuit Diagram of Solar Photovoltaic Cell [5]

4.4 Significance of Solar Energy Prediction

The following literature review confirms vibrant anticipation towards the research objective. The literature significance the solar energy prediction establishes financial management (reduction of worst-case computational cost), the rapid increase in the national economy, efficient use of fluctuating energy sources, complexity in system performance, regulating optimal policy, and minimizing the risk of incorporating solar PV cells with the grid. These essential features urge the intention of incorporating solar energy prediction in the research context.

For the forecasting of weather patterns, the researchers [7] suggested using an Evolving Polynomial Neural Network (EPNN) (global solar irradiation, air temperature, relative humidity, and wind speed). Mean Relative Error (MRE) for the whole data set does not go beyond 15.4%, and the correlation coefficient (R2) is organized between 0.9821 and 0.9923. Compared to existing ANN's design, including wave net (wavelet-network) and Adaptive Neuro-Fuzzy Inference Scheme, the suggested model yields more precise predictions (ANFIS).

According to the study's authors [8], both developed and developing nations have become increasingly interested in investing more money into PV systems in recent years, with the goal of increasing the efficiency of these systems so as to reap the environmental and economic benefits of converting solar energy into electricity. The effects of dust deposition, humidity, and air velocity will be examined independently, and their interplay will be elucidated. It is shown that all three parameters have an impact on the other two, and it is argued that considering their combined impact on solar cell design is essential for gaining a comprehensive understanding of the topic.

While The researchers [9] postulated studies of the Mediterranean–concentrated solar project which indicated Iran can be a part of the Mediterranean renewable power generation chain in 2050 to present the electrical power demand of Europe. The aspire of that study was to decide the theoretical solar irradiation potential in Iran by using an niroo research institute irradiation model based on the geographical and meteorological data. Outcomes of their study made apparent that the offered solar atlas could provide suitable tools for primary study of solar energy potential and extracted energy in Iran.

Predicting solar irradiance (for up to a day or longer) is something that academics [10] have suggested is of importance for grid-connected PV Plants, standalone, and hybrid 17 systems. Outdoor data acquired by horizontal mount pyranometer on June 24th, 2012 at coordinates (2.945N, 101.728E) are compared with the projected findings. A comparison of the suggested model's performance with field data revealed a high correlation coefficient of 97%; this figure was also reported for Hottel's (96%) and Ashrae's (76%) models.

Researchers [11] recommended doing so on the premise that solar radiation intensity has a proportionate effect on solar power output. The accuracy of the Back Propagation Neural Network (BPNN) prediction model is greater than that of the other empirical models, as shown by the experiments. Good findings from the prediction approach provide the groundwork for further studies in this area that will focus on forecasting solar radiation levels.

The researchers said that their current contribution [12] provided more evidence that it is possible to make accurate predictions of PV power using just basic data and no meteorological information at all. Accurate planning and scheduling choices have to be made without access to weather data due to the possibility that it would be too costly to regularly get predicted weather data or that contact with meteorological services might break down. The work's approach for data pre-processing and the building and validation of forecasting models exhibited generalizability, making it applicable to other kinds of time series and different data mining methodologies.

It was this study that the researchers [13] drew upon to determine when a hybrid solar PV/Diesel/Battery system would reach price parity with the grid in the United States, Germany, Pakistan, and South Africa. When determining when grid power parity would be reached, the cost per kilowatt-hour was compared to the predicted price of energy from the grid in each area. They concluded that the reduction in micro grid pricing was not the primary cause of grid parity, but rather increased electricity prices or unstable systems.

In the opinion of the researchers [14], solar energy will play a significant part in the world's future energy supply. Integration of high insolation solar energy into the national power system required accurate predictions of future solar energy production. Given the unpredictable nature of solar power, effective use was made possible by the availability of accurate forecasts at several scales of time and space. A study of solar radiation prediction and its application to a fast developing country like India was prompted by the current state of solar irradiance forecasting for energy production.

Solar-powered sensor networks, as the authors of a recent study [15] point out, need careful attention to energy management. Its data-routing rules were calibrated to maximize efficiency in solar-powered networks. Initially, the best strategy in certain circumstances was being obtained by forward dynamic programming. When doing so was computationally viable, there was a correlation between the optimum policy and the greedy policy's performance. Analyzing the greedy policy's performance and computational difficulties across randomly generated networks revealed that it produces outcomes that are somewhat comparable to those of the optimum policy, but at much lower worst-case computational costs and memory needs.

The researchers [16] found that mistakes in estimating PV power production might originate not just from anticipating irradiance, but also from the conversion of irradiance to real PV power generation, and that these inaccuracies were commonly underestimated. Using a case study from China's Henan province, researchers assessed forecasting's monetary worth. It was shown that revenue losses might occur even when forecasting frequencies and prediction corridors deviated by just a small amount from what was required (i.e., discounted payback period, net-present value and internal rate of return).

Researchers [17] came to the conclusion that precise solar power forecasting is necessary for its incorporation into the electricity system. Prediction Interval (PI) construction for solar power was ideal for its nature of high variability, according to the older research, which focused primarily on increasing the accuracy of point forecasts by a factor of 14. A new and enhanced bootstrap technique is offered to supplement the standard theoretical methods. Two years' worth of PV data from the University of Queensland were validated by using a range of various prediction horizons (5 minutes, 30 minutes, 1 hour, 2 hours, and 6 hours).

5. Artificial Neural Networks (ANN)

A neural network is made up of a bunch of basic components that all function together in parallel. The human and animal nervous systems served as models for these components. The network's operation, like that of a natural system, is primarily dictated by the relationships between its nodes. Changing the weights of the connections between nodes in a neural network enables one to "train" the system to carry out a desired task. Typically, neural networks are "trained" to respond to certain inputs with the desired results. For an example, see Fig. 1. After comparing the network's output to the intended outcome, the network is then fine-tuned to get an outcome that is consistent with the input. In order to train a network, it requires a large number of examples like this. [18]

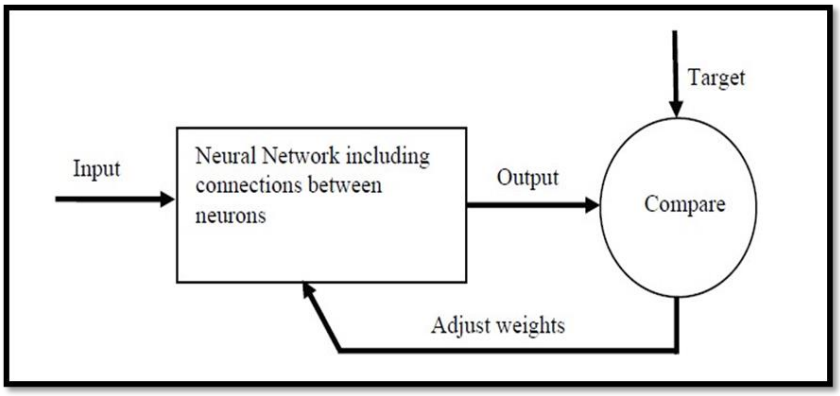

Figure 2. Basic Principles of Artificial Neural Networks [18]

5.1 The Applications of ANN

ANNs have been applied successfully in a number of application areas. Some of the most important ones are: [19]

- *Function approximation:* A function approximation is a mapping from a set of inputs to a fixed number of outputs. Adaptive model-free estimate of parameters makes this possible, as opposed to most standard statistical methods.
- *Pattern association and pattern recognition:* This is a problem of pattern categorization, and it has two aspects: pattern association and pattern recognition. Artificial neural networks (ANNs) are a powerful tool for tackling complex issues in this area, such as audio/visual recognition. Even without knowing the pattern in advance, you can do this job. When this happens, the network picks up on completely novel patterns.
- *Associative memories,* or the challenge of remembering a pattern from a partial cue. Network architectures employed in such applications are often intricate, made up of a large number of dynamic neurons that interact with one another.
- *Generation of new meaningful patterns:* a very recent area of application. It has been argued that the right configuration of neurons may display some primitive forms of creative ability. Successful applications of ANNs may be found in many different disciplines, including mathematics, engineering, medicine, economics, meteorology, psychology, neuroscience, and many more. Most notably, these may be found in the fields of pattern, sound, and voice recognition; the study of electromyographs and other medical signs; the identification of military targets; and the detection of explosives in checked luggage, among other places. They have also found use in areas as diverse as the prediction of weather and market trends, the prediction of locations for mineral exploitation, the prediction of electrical and thermal loads, and the management of adaptive systems and robots. Because of their ability to construct predictive models of the process from multidimensional data frequently acquired by sensors, neural networks are utilized for process control [20].

An input layer, several intermediate layers, and an output layer are the standard components of a network. A basic network consists of one neuron coupled to the neurons of the layer below it through synapses with variable weights. In most cases, information is kept as a matrix of relative weights between nodes (presumably corresponding to synapse efficacy in biological neural systems). When employing an appropriate learning approach, training entails systematically adjusting the weights of the connections between nodes. In the network's learning mode, an input and its intended output are given, and the weights are modified such that the network produces the output. Before training, the weights are random and have no significance, but after training they contain useful information. [20]

The information processing at a single node is shown in Figure 3. Through its outgoing connections, the node gets activation of various weights from other nodes. Initially, we total these (summation). A node is activated after the result is fed into an activation function. The activation value is multiplied by the connection weight and sent onward to the next node.

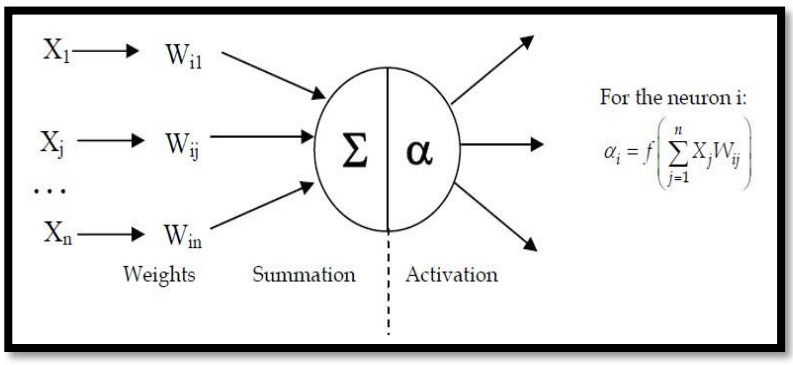

Figure 3. Information Processing in A Neural Network Unit [18]

5.2 Application of Artificial Neural Network in Energy Sectors

The following literature illustrates the application of ANN in nonrenewable energy, RE and specifically in solar PV power generation. The 18 following literature establishes various applications while incorporating ANN in solar energy power generation; they are smart energy management, automatic system configuration, and modelling, optimal operation in grid connected solar PV cells. Subsequently, includes literature from other RE system to establish features such as configuring wind energy generation, configuring biogas production, troubleshoot the problem with a degree of uncertainty, Hybrid Renewable Energy (HRE) management and regulating the controllers in RE power generation. Literature review on non-renewable energy includes modelling and configuring nuclear power plants, fossil fuels, and diesel engines.[5]

5.3 Applications of Artificial Intelligence (AI) Techniques in the Solar Energy Applications

Several studies have employed AI methods to improve solar power systems. An introduction to these software packages is provided here. Table 1 summarizes a few cases where artificial intelligence was used to improve solar energy applications.

Table1. Summary of Numbers of Applications Presented in Solar Energy Applications [18]

AI technique	Area	Number of applications
Artificial neural networks	Prediction of solar radiation	11
	Modelling of solar steam-generator	1
	Prediction of the energy consumption of a passive solar building	1
	Characterization of Si-crystalline PV modules	1
	Efficiency of flat-plate solar collectors	1
	Heating controller for solar buildings	1
	Modelling of a solar air heater	1
Fuzzy logic	Photovoltaic solar energy systems	2
	Sun tracking system	1
	Prediction of solar radiation	5
	Control of solar buildings	1
	Controller of solar air-conditioning system	2
Adaptive Network based Fuzzy Inference System	Prediction of solar radiation and temperature	3
Genetic algorithms	Photovoltaic solar energy systems	2
	Determination of Angström equation coefficients	1
	Solar water heating systems	2
	Hybrid solar–wind system	2
	PV-diesel hybrid system	2
	Solar cell	1
	Flat plate solar air heater	1
Data Mining	Solar cell	1

5.4 Application of ANN in Renewable Energy

Researchers [22] argued that increasing shares of renewable energy sources like wind and solar dramatically raise the already high degree of unpredictability in power grids. To put a number on the many forecasting uncertainty that may arise. An NN-based strategy for PI generation was put into place. This formulation contained fewer parameters and was more directly related to the central issue than the cost function. Results from previous research showed that the suggested method could rapidly build better quality PIs for forecasting both demand and wind power output.

While the researchers [23] had investigated the factors, which could affect the accuracy of short-term wind speed prediction when finished more long periods spanning dissimilar seasons. Two types of NN were used to forecast power generated via precise horizontal axis wind turbines. Outcomes had exposed that seasonal variations involve the prediction accuracy of the wind resource, but the magnitude of this authority powerfully depends on the information of the NN deployed.

The researchers [24] recommended that RE systems were taking place than the conventional energy systems. Particularly, PV systems and Wind Energy Conversion Systems (WECS) were taking a big role in supplying world's energy requirement. However, ANN had much usage were as in modelling, simulation and control of RE systems. In their proposal ANN applications of PV, WECS and HRE system, which consist of PV and WECS, were present; Usages of NN structures in such types of systems had been motivated.

The researcher [25] approached that NN were becoming helpful as an exchange way to classical techniques. They had also been applied for modelling, recognition, optimization, prediction, forecasting, evaluation, classification, and control of complex systems. The study offered different 23 applications of NN used in wind energy systems. In the proposed method applications of NN in wind energy systems, could be grouped in three major categories: forecasting and prediction, prediction and control, identification and estimation and their major intention was to present an overview of the NN applications in wind energy systems.

The researchers [26] had suggested that the energy consumption control in energy intensive companies was constantly considered as additional critical activity to continuously develop energy performance. They had offered an entire new approach to energy consumption control by proposing a methodology based on ANN and had intended at creating an automatic energy consumption control system. The common purpose of their work was to permit the automatic utilization of that kind of tools, so a method to categorize a lack of accuracy in their model and two dissimilar retraining techniques were proposed and compared.

The researchers [27] had investigated and develops in the field of RE which had been growing due to the need of RE as an extended and reliable source of energy. According to them AI techniques such as ANN, fuzzy logic and GA had been extensively used to deal with these troubles in the field of RE and though there were problems with a degree of uncertainty need bayesian networks as that was one of the most efficient theories to face.

The researchers [28] brought forward that power generation from RE resources was on the increase in most countries, and that trend was predictable to continue in the near future. The major forecasting approaches utilize physical, statistical, AI and hybrid methodologies. Their study had provided the rationale for forecasting in power systems, a concise analysis of forecasting methods as well as an evaluation of their presentation as applied in the literature. Their methods for improving the accuracy of forecasts had been presented jointly with key forecasting problems and developing trends.

The authors of the study [29] state that may be used to simulate the working conditions of a miniature wind generator set in counter-rotation. The MSE was used to verify the network's quality. The design of the turbine allows for the angle of the blades' wedge and the distance between the rotors to be adjusted at any time of the night. To maximize the amount of electricity produced by the wind turbine, the created network model may be utilized to optimize the controller's programming in the future.

Applications for ANN, first suggested by researchers [30], have expanded greatly over time. Microgeneration using a combination of renewable resources was studied. Six artificial neural network (ANN) control logics were evaluated after a controller was constructed in the MATLAB environment to forecast the future temperature of the room. The study 21 found that using techniques based on artificial neural networks (ANNs) might reduce primary energy

consumption (by up to 36%), operational expenses (by up to 81%), and carbon dioxide equivalent emissions (by up to 36%).

The goal of this study [31] was to use machine learning techniques to evaluate Mashhad, Iran's electrical energy consumption and to suggest novel approaches for arousing locals' enthusiasm for renewable energy generation by drawing on the knowledge of experts in the field. The novel integration of ANN technology with statistical analysis in the development of a decision-making tool is one of the most intriguing aspects of this research (DSS). Finally, over the course of a year, we simulate a PV system to assess the solar energy potential in Mashhad, Iran. The Classical Delphi (CD) technique is used to implement TP and develop incentive programs. For this, 45 specialists are asked for their opinions on various motivational strategies, which are then ranked in a series of expert meetings. The results of the research indicate that the ANN model can estimate electrical energy consumption with a 99% degree of accuracy throughout both the summer and winter seasons. Then, based on the PV system's solar energy calculations, the peak of electrical energy demand may be handled either in the hottest or coldest months. A4 (sharing benefits of optimized costs with the citizens by solar energy generation), B2 (reducing the electrical energy cost for solar energy generation, especially during peak times), and C1 (creating the energy coin in the city with credits instead of spending money in urban activities fits to solar energy generation) emerge as the primary motivational strategies for solar energy generation, based on the combination of professional and public opinion.

5.5 Application of ANN in Solar Photovoltaic Power Generation

Daily worldwide solar radiation data was modeled and predicted by the researchers [32] utilizing meteorological data such air temperature, sunlight length, and relative humidity. For the purpose of forecasting the daily global sun radiation, four RBF-models were created. The RBF-model, which took into account both sunlight and air temperature, was found to be reliable, with an R2 of 98.80 percent indicating that the model accurately predicted the observed relationship between the two variables.

The researchers [33] intended to use ANN to develop a method for predicting solar energy output. The amount of global and diffuse sun irradiation received were calculated based on an ANN's prediction of a clearness index. The ANN model used a feed forward multilayer perception model that required four inputs and produced a single output. Diffused solar irradiation was then computed as a function of global solar irradiation and the clearness index using the site-specific solar irradiation measurements.

Significant work on RE electrical system planning and operation was accomplished when researchers [34] demonstrated the value of PV electrical power forecasting for the optimum operation and power prediction of grid-connected PV facilities. The paper investigated the use of NN to analyze the design of PV electricity forecasting systems for one week ahead in 2013 utilizing meteorological datasets that included global irradiance and temperature data from Ghardaia city in the south of Algeria.

The method of utilizing ANN to forecast solar radiation was suggested by the study's author [35]. Using data on sunlight intensity, number of days, and geographic locations, the constructed model accurately forecasted three weather factors. The average percentage error in estimating solar radiation was 1.3%, whereas the MSE was 1.8%, and the MBE was 0.3%. While the MAE, MSE, and MBE values for predicting ambient temperature were 1.3%, 1.7%, and 0.4%, respectively, this was still a significant margin of error.

In order to estimate the power output of a PV system in real time, researchers [36] proposed an ANN trained only on solar radiation data. An autonomous general-purpose neural hardware generator was utilized in their study to facilitate the hardware implementation of an ANN using a Field Programmable Gate Array (FPGA). This instrument enabled an automated configuration mechanism, which frees the user from the specifics of the ANN's physical implementation and allows for setup.

Researchers [37] proposed a method for multi-hour forecasting of hourly worldwide horizontal sun radiation time series, and they used regularly and easily available observed meteorological solar radiation to anticipate a small-scale solar radiation database for a period of 1 day. In the first step, we employed the Auto Regressive-Moving-Average (ARMA) model to project the global solar radiation time series into the future. Next, a Nonlinear Auto Regressive (NAR) NN model was employed to make predictions because of the nonlinearity in the solar radiation time series.

It was hypothesized by the researchers [38] that the AI model was used to try and guess at what would happen in an uncharted region. The input layer, hidden layer, and output layer were all under the ANN's control. It was found that a combination of six distinct training algorithms worked well in ANN to boost performance.

Researchers [39] anticipated that the rising prevalence of solar PV technology would provide a challenge for validating intelligent energy management platforms. The solar PV installations' output of electricity was spotty. Neural Network (NN) and wavelet transform hybrid model was used to predict solar energy output. The above-and-beyond results of their intended method were compared to those of other existing techniques like ANN, and were determined to be better within the specified bounds, hence the method was

With data from a NWP model and calculated astronomical variables, the researchers [40] developed a technique based on ANN and presented an Analog Ensemble (AnEn) to construct deterministic and probabilistic predictions of power output by PV power plants over the course of 72 hours. The results showed that the best results could be achieved by combining AnEn and ANN solutions, and that the suggested system was amenable to being implemented on a huge scale.

The researchers [41] set out to develop a system that would use machine learning methods in tandem with data from a Numerical Weather Prediction model to accurately predict the amount of energy that will be generated by a solar array in the future. In order to predict power outputs from a real installation in Puglia, an Artificial Neural Network (ANN) model is trained using data from the Global Data Assimilation System (GDAS) sflux model (southern Italy). The power outputs and climate sensor data provide a baseline for the PV system's performance. Three separate venues for practice and testing will be used. In the first, acquired meteorological data is used to train the ANN model, which then predicts power outputs. Second, instead of using monitoring data for training, GDAS data is used for predicting. The final set relies on the GDAS weather data for both its training and prediction purposes. The results show that the tested numerical weather model can be linked with machine learning technologies to reliably anticipate PV system output to within 10%, even without access to in-situ weather measurements.

The researchers [42] develop ANN algorithms with the ability to predict solar irradiance and solar PV parameters on an hourly timestep with greater accuracy. All of the potential sites are fed into a deep learning regression model that is trained and tested with the help of the Levenberg-Marquardt back propagation technique. Using all of the input parameters, four unique ANN models were created in Keras Python for each site. In this research, we employed the following statistical measures for evaluation: R, R2, RMSE, and Mean Absolute Error. Parameters of solar photovoltaic systems may be predicted with the use of the created models. The ANN models have a R value between 0.9046 and 0.9777 for predicting solar irradiance, and between 0.7768 and 0.8739 for predicting solar PV multi-parameters.

6. Conclusion

This paper shows that artificial intelligence approaches have been used in a variety of contexts for solar energy system modeling, prediction, and control. Data representing the actual system's historical history and performance is needed to build up an AI system, together with the selection of an appropriate model. This paradigm is often chosen after experimentation with several potential approaches.

In this article, we took a look at the several forms of AI currently in use in solar energy systems. Likewise, summaries of relevant publications from the scholarly literature that have been published are provided. As an alternative to more traditional methods, AI techniques are becoming effective. Engineers, economists, physicians, soldiers, sailors, and others have all found useful applications for AI. Modeling, identifying, optimizing, predicting, and controlling complex systems are among areas where they have been used. Artificial intelligence methods have been effectively employed in many different solar energy applications, as shown by the examples provided. This list of applications for AI certainly isn't meant to be all-inclusive, but rather to serve as a representative cross-section of the wide range of conceivable uses for AI. Artificial intelligence approaches have their own set of relative benefits and drawbacks, just like any other approximation methods. There is no hard and fast rule for determining when this method will work best. It is considered, based on the research described here, that AI approaches provide an alternate approach that should not be discounted.

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