Research Article

Deep Learning Based on Wireless Remote Sensing Model for Monitoring the Solar System Inverter

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Traditional energy sources have become one of the most serious causes of environmental pollution because of the growing demand for energy. Because of the carbon emissions that have recently increased greatly, we had to search for a safe, cheap, and environmentally friendly energy source. Many photovoltaic (PV) solar panels are used as an energy source because of free and environmental friendliness. However, this technology has become a source of inspiration for many researchers. The proposed method suggests to extract useful features from PV and wind generators and then train the system to control them and update the inputs according to prediction results. Solar energy produces energy that varies according to the external influences and the immediate changes in weather conditions. Solar panels are connected through an inverter with the grid, through which the work of the solar panels is monitored using the Internet. It is worth using neural networks (NN) to control variables and adopt system output of previous iteration in processing operations. Use of deep learning (DL) in the control of solar energy panels helps reduce the direct surveillance of the system online. Solar power generation systems mainly depend on reducing the pollution resulting from carbon emissions. Saving CO₂ emission is the main purpose of PV panel cells, so smart monitoring can achieve better result in that case.

1. Introduction

With regard to the increasing population density, which has become uncontrollable, consequently, the requirements of life have increased according to technological development. The electric power network is one of the largest and most complex networks that supply electrical energy to citizens, so there must be economic feasibility in transmitting and generating this energy [1]. It is imperative to provide the increasing demand for electric power with the lowest acceptable cost in order to reach the level of environmental safety [2].

Therefore, it is imperative to plan future needs for electricity taking into account the integration resources of environmentally friendly energy and to ensure that sufficient reserves are in place to meet the load demand increasing [3]. It is imperative to maintain the reliability of electricity, the

absence of interruptions in electricity services, and the integration of citizens with government agencies. Studying a clean and alternative power generation system and equipping it properly is the main purpose of this study.

Three main issues that control the electrical system are as follows. First is power generation. Generation comes on the main level in terms of importance. The second issue that controls the supply of electrical energy is the transmission which is responsible for transmit the power from source generating to the destination demands [4]. The third issue that affects the electrical system is the uniform distribution between local networks. Since our study includes controlling the solar energy generation system, therefore, we must take into consideration the three issues that determine electrical energy [5].

The increase in pollution results from burning fuels due to the increasing demand for electric power in addition to

the generation of harmful gases, such as CO_2 , that cause contamination of the environment [6]. Therefore, modern methods of generating electrical energy, which are environmentally friendly, are used; solar energy is one of these methods and has a very high efficiency, at the present time. The carbon emission in 2013 was 32.2 billion tons, which increased over the record in 1990, which reached a maximum of 56.1%, and also in 2012, its percentage was more than 2.3%. Therefore, the use of alternative clean energy is a major reason for reducing carbon emissions [7]. Solar cell technology has increased nowadays due to increasing technological development. New technologies enable us to control the efficiency of energy generation in this context which can be exploited in the smart home, and deep learning is a technology that uses smart technology in smart cities [8]. Any system including the PV system when managed by deep learning should be understood first in order to get utmost benefit. Training such system is not easy and needs more experience and costs time under fixed conditions [9]. Due to the proposed system which is managed remotely, we have to train the remote-sensing system to be able to adapt with the deep learning system. It is worth using electric grid of the energy when neural network (NN) system is used and run accordingly.

Many existing studies have contributed in remote monitoring of solar energy and solar cell power generation. Table 1 summarizes the most important studies in this field.

The research is structured as follows. Section 1 gives definition and introduction for the techniques and used tools. Section 2 introduces energy systems such as solar and wind generator. Section 3 introduces the techniques that will be used in the proposed method. The proposed method is discussed in detail Section 4. Then, result analysis is illustrated in Section 5 for analysis and discussion. Finally, Section 6 at the end of the research gives proper summary of the research.

2. Solar and Electrical Energy System

Electrical energy is obtained from solar energy by using PV cell. The PV cell can be defined as a converter of light obtained from the source energy into electricity directly via photovoltaic effect [17], as shown in Figure 1.

Many variables when using photovoltaic cells can be taken into consideration such as voltage, current, resistance, and time. PV panels consist of a number of solar cells combined together to form a module [18]. PV silicone when exposed under sunlight generate Volte around 0.5 to 0.6 Volte. The PV cell can be used as a photodetector which can sense light or electromagnetic radiation and measure light intensity. Maximum Power Point Tracking (MPPT) is an algorithm that is usually used with PV to extract maximum power under all conditions. Output energy gain is based on the relation between temperature and resistance in the nonlinear manner. The relation between produced I and V affects the efficiency of the PV system.. Maximum load is determined by external environment effect such as temperature and proper gain. MPPT, sometimes, is called increment conductance, constant voltage, or temperature technique.

Each structure of solar power generator is classified based on converters' design, which is PV commercial available. Three classes, according to inverter distribution, are centralized inverters, microinverters, and string inverters [19]. Structure of string and central PV system is almost similar based on the distribution of the inverter inside the grid or array. The connecting inverter inside the solar array reflects the manner of designing the Solar System. Connecting the inverter to the array of photo cells in both string and central somewhat is costly but worthy. In this study, we consider the central PV system, as shown in Figure 2.

PV solar cell is arranged as the array to connect through the system and inverter and consider the main issue in monitoring.

3. Deep Learning

With the development in data science and modern technology, such as big data and high-performance computers, an opportunity is provided for machine learning to understand data and behavior of it through complex systems. Machine learning gives the machine the ability to learn in different algorithms without strict orders from a certain program or limited instruction [20].

Deep learning can be defined as a technique of machine learning to learn useful features directly from given images, sounds, and texts. Many layers are exploited by deep learning for nonlinear data processing of unsupervised or supervised feature extraction for classification and pattern recognition. Deep learning motivation is greatly reduced by artificial intelligence (AI) area, which simulate the ability of the human brain in terms of analyzing, making decision, and learning [21]. Deep learning goal is to emulate approach of hierarchical learning of extracting features by the human brain directly from unsupervised data.

The core of deep learning hieratically computed the features and representation of information, such as defining the features starting from the low level to the high level [22]. Many applications are provided by the tolls of machine learning [23]. With the normal solar PV system, the standard techniques of machine learning do not work well when running directly because of ignoring the nature of grid distribution. Deep learning features are extracted automatically from the given PV solar inverter. The characteristics of this method of features are considered in one of the learning in the system.

Characterization of input data used as a feature is the key issue to success of processing PV system. There are limitations during control and monitoring PV solar system. For this reason, we can use deep learning by its feature extraction to solve limitation in such field.

As mentioned before, the main difference between machine learning and deep learning is the features' selection method [24], as shown in Figure 3.

Features in deep learning will be generated automatically to simulate the appropriate results. Different hidden layers participate in decision-making by using the feedback from the next layer that will feed back to the previous layer [25]. DL enables computers to perform complex calculations by

TABLE 1: Most important studies in literature which considered remote monitoring of solar energy.

Authors	Method	Achievement
[10]	Examined grid connected domestic PV array	High extra solar power store in the battery
[11]	Battery storage EMS for a rooftop PV system	Increase daylight power even when cloud
[12]	Grid connected hysteresis current control solar PV	Current, inverter track, and current of solar PV system
[13]	Photovoltaic with storage devices (lead-acid battery) and AI system	Maximum remote sensing of PV
[14]	Designed H/W and S/W via IoT	More control on temperature
[15]	Effective optimization algorithm by web monitoring	Control over large area
[16]	Internet of things (IoT)	Enhances the maintenance and the performance of the system

FIGURE 1: How PV converts light to electricity?

relying on simpler calculations to optimize computer efficiency [26]. It is difficult for a computer to understand complex data such as national or PV grids (under certain environments) or a series of data of a complex nature, so we use deep learning algorithms instead of usual learning methods [27].

4. Proposed Method

Day by day the demand for electricity is increasing. Owing to deficit in the fuels, especially in poor countries, and the harms to the environment caused by power generation, solar energy is becoming very popular and demanding. This kind of energy is considered free from pollution and is also available free of cost all over the world. Due to its free availability, we need to consider this power source and improve the solar energy monitoring to get the optimal

performance. Remote monitoring already exists, and there is need to improve optimal load performance and scheduling. The proposed diagram for monitoring PV panels is displayed in Figure 4.

There are many methods for monitoring and acquisition; the data are listed as follows:

- (i) **Wired monitoring:** by this technique, wire is used to gather information of automatic transmission and then used to measure the data remotely from the sender to the receiver by wire communication. Wireless monitoring aims to avoid any physical communication and remotely control and record the results.
- (ii) **SCADA:** it is a system aiming to control the grid remotely from different locations, and real time is important here.

FIGURE 2: Inverter structure in central class.

FIGURE 3: Deep learning system of PV solar cells.

- (iv) Cloud computing monitoring: it is based on a computer system and the demand from the local or a remote location which aims make data available over the Internet and control remotely.
- (v) IOT monitoring (Internet of things): it is carried out using physical connection devices on the Internet and connecting other devices or any hardware in such case monitoring will be remote as well as under control.

In this study, we focus on clouding monitoring that uploading data over the cloud is necessary so it can request them anytime and anywhere.

In terms of feature extraction from given parameters, we have to update the parameters' weights every day. Neural network (NN) is designed to be adaptive with fixed and variable parameters such as results or decision may be fed again to other hidden layers as input. Many parameters are

FIGURE 4: Diagram of the proposed method.

taken into consideration, such as winds, sun direction, temperature, and clearance of the air.

Any variable, no matter how small, must be taken into account by the proposed system, such as angle of sunlight or humidity, as shown in Figure 5.

As for the angle of inclination, it is chosen to obtain the highest intensity of solar radiation, especially in the summer, and we know that the sun rises at a large angle of elevation and gradual, which means there will be more than one value, not the energy output depending on the angle; the system, as we mentioned, is of the fixed type that does not move with the sun (no tracking), where the angle of inclination ranges from zero degrees horizontally to 90 degrees vertically.

Figure 6 illustrates how to calculate the angles according to sun light direction movement.

Height of the panel and its angle can be found from the following equation:

$$x = \sin \text{Tilt}^\circ \times \text{length},$$

$$y = x \times \frac{\cos(\text{azimuth angle})}{\tan(\text{altitude angle})}, \quad (1)$$

where $(\text{Tilt})^\circ$ represents the angle of the panel with horizontal ground, which is variable according to the time.

Connecting the inverter to the web through WIFI network, all information regarding the grid of the PV solar panel is updated simultaneously. The inverter is responsible for modulation of the power obtained from panels to the grid or the end user. Therefore, all data collected from outside or inside the system are used as features in addition to the result data to accumulate information and updated parameters supervised by the system automatically and end operator monitoring through the web.

The proposed system aims to increase the performance of PV solar cells and reduce the fuel consumption in addition to controlling or saving CO_2 emission, which is explained in detail in Section 5.

For better illustration of the proposed method, the whole system is summarized in Figure 7.

The deep learning method is based on how to extract the features and quality of them. In green energy and proposed method, we used two types of green energy generators which are solar and wind. In the proposed method, we considered many features to learn the system and then choose the appropriate results in terms of control.

5. Experimental Results

The proposed system allows us to make complex computation for better evaluation. Most of PV panel cells' system aims to reduce the cost, both commercially and environmentally. For this reason, our study was proposed. Firstly, cost of generation reduced by using deep learning (DL) due to the system simulates the whole environment and makes decision immediately without the need for online monitoring. Training of the system begins with offline grid and with a system of 38 invertors. The system automatically adopts the structure of PV panels, as shown in Figure 8.

Energy produced from solar panels within on-grid goes through the main grid, generating part of demanding power. Therefore, the consumption of diesel generators will be reduced due to the lower loads.

Another goal of the research is to reduce CO_2 emissions. Solar generators are known to be environmentally friendly, so they contribute very greatly to reduce environmental pollution. Figure 9 shows how the system participates to save the environment.

The efficiency of the system is measured in terms of saving the society and the environment, in addition to the important factor: the material cost. Tables 2 and 3 also show

FIGURE 5: Sunlight angles changing throughout the day.

FIGURE 6: Direction of PV solar panel under the sun.

FIGURE 7: The proposed method within the system.

Project and Simulation variant

Project: 15 KW Solar Engery
 Simulation: New simulation variant
 PV Array, Pnom = 5.4 kWp
 PV module: Poly 285 Wp 72 cells
 System: Stand Alone System

Values

☒ Global ☐ By Wp
☐ By piece ☐ By m²

Investment

PV modules	19 units of 285 Wp	0	€	☒	
Supports / Integration		0	€		
Batteries	56 of 12 V/ 160 Ah	0	€	☒	
Controller		0	€		
Settings, wiring, ...		0	€		
Others, miscellaneous...	<input type="button" value="Details"/>	0	€		
Substitution underworth	-	0	€		
Gross investment, (excl. taxes)		0	€		

Financing

Taxes: 15.00 % 0 €
 Subsidies: - 0 €
Net investment: 0 €
 Annuities: 0 € / yr
 Running Costs: 0 € / yr
Total yearly cost: 0 € / yr

Loan

Duration: 20 Years
 Rate: 5.0 %
 Ann. factor 8.02 %cap./yr

Currency

Europa - EU

Energy cost

Used solar energy: **8408** kWh / year
 Excess energy: **825** kWh / year
 Yearly cost: **0** € / year
 Used energy cost: **0.00** € / kWh

FIGURE 8: Cost estimation for the training mode.

FIGURE 9: The proposed system of saving emission.

the solar capabilities and radiation throughout the months of the year which are extracted from the computer simulation program.

The system is implemented in two phases: the first is called training, which simulates the system with the data,

and the second phase is the testing phase, where the system is connected to the local grid.

In terms of accuracy, the results of the proposed study are considered good when compared with previous studies as presented in Table 4.

TABLE 2: Factors related to PV solar cells.

	GlobHor (kWh/ m ²)	DiffHor (kWh/ m ²)	T Amb (°C)	WindVel (m/ s)	GlobInc (kWh/ m ²)	DifSInc (kWh/ m ²)	Alb Inc (kWh/ m ²)	DifS/ (Gl)
January	92.9	36.67	7.19	1.7	138.7	44.51	1.244	0.000
February	112.7	42.81	10.34	2.1	153.3	51.21	1.508	0.000
March	156.0	66.09	15.03	2.3	184.4	72.79	2.088	0.000
April	180.2	82.17	19.30	2.3	184.4	84.40	2.412	0.000
May	220.8	83.71	25.45	2.3	213.1	82.58	2.957	0.000
June	237.2	72.87	30.50	2.5	218.0	70.44	3.165	0.000
July	234.3	80.48	33.67	2.5	220.1	78.49	3.131	0.000
August	218.6	71.19	33.07	2.1	223.3	73.36	2.926	0.000
September	179.9	55.81	27.87	1.9	207.5	62.56	2.410	0.000
October	145.2	46.39	22.84	1.6	191.8	56.20	1.944	0.000
November	103.3	36.28	13.81	1.4	152.7	45.17	1.383	0.000
December	84.1	33.60	9.05	1.5	129.6	41.47	1.126	0.000
Year	1965.2	708.07	20.74	2.0	2222.2	763.21	26.295	0.000

GlobHor: horizontal global irradiation; DiffHor: horizontal diffuse irradiation; T Amb: ambient temperature; WindVel: wind velocity; GlobInc: global incident in coll.; DifSInc: sky diffuse incident in coll.; Alb Inc: Albedo incident in coll.; DifS/G: incident sky diffuse/global ratio.

TABLE 3: Performance related to PV solar cells derived from the simulation system.

	Yr (kWh/m ² .day)	Lu	Yu (kWh/kWp/d)	Lc	Ya (kWh/kWp/d)	Ls	Yf (kWh/kWp/d)	PR
January	4.47	0.000	4.47	0.411	4.06	0.082	3.98	0.890
February	5.47	0.000	5.47	0.624	4.85	0.506	4.34	0.794
March	5.95	0.189	5.95	1.044	4.90	0.561	4.34	0.730
April	6.32	0.589	6.32	1.613	4.71	0.364	4.34	0.687
May	6.87	0.795	6.87	2.159	4.71	0.370	4.34	0.632
June	7.72	0.910	7.27	2.550	4.72	0.374	4.34	0.598
July	7.10	0.692	7.10	2.389	4.71	0.368	4.34	0.612
August	7.20	0.766	7.20	2.497	4.71	0.363	4.34	0.603
September	6.92	0.709	6.92	2.206	4.71	0.367	4.34	0.628
October	6.19	0.331	6.19	1.473	4.71	0.368	4.34	0.702
November	5.09	0.012	5.09	0.669	4.42	0.078	4.34	0.853
December	4.18	0.000	4.18	0.417	3.76	0.118	3.65	0.872
Year	6.09	0.418	6.09	1.509	4.58	0.325	4.25	0.699

Yr: reference incident energy in coll.; Lu: normalized unused (full battery); Yu: normalized potential production; Lc: normalized array losses; Ya: normalized array production; Ls: normalized system losses; Yf: normalized system production; PR: performance ratio.

TABLE 4: Accuracy of the proposed method compared with existing methods.

Researchers	Method used	Accuracy
[28]	Deep learning and IoT	92.77
[29]	Hybrid deep learning	91.99
[30]	CNN-LSTM	93.51
Proposed	New features: DNN	94.65

Results of the system reflect the performance and worth of the system. As a matter of fact, the complexity of design features extraction and directs the system to increase the hidden layer by suggesting new features according to the environmental change which is worthy.

6. Conclusion

In this study, a proposed method was designed for alternative energy, which is environmentally friendly, often needs management, and can be controlled to increase production efficiency. At the present time, due to the development in the field of software, especially deep learning, it

has become possible for organizations to be managed electronically according to real-time data and outputs. Monitoring (the inverter device) through modern systems remains unable to respond immediately. From here, the use of deep learning has become important to obtain automatic control of the inverter. Many influences and variables hinder the work of the solar system, but by using smart methods, the system can be made instantly adaptive to the circumstances. During training mode, the system achieved good performance as reported in Section 5. The proposal for future work can be with automatic orientation towards sunlight and the calculation of features extracted from it in order to be processed.

Data Availability

All data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors confirm that there are no conflicts of interest regarding the study of this paper.

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