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A Day Solar Photo-Voltaic Plant Prediction Using Machine Learning Algorithms

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ABSTRACT

Renewable energy sources are a viable option for bridging the power industry's continuous supply gap. Solar energy is the most advantageous of all renewable energy resources since it is available worldwide, unlike other geographically limited resources. For this enormous solar system implementation, sophisticated frameworks for remote plant monitoring using a Raspberry Pi-based interface are required. Because most of them are located in difficult places, monitoring them from a single location is impossible. This system measures the voltage, current temperature, and light intensity. The system is implemented using raspberry pi. The data logger system is also implemented in this system. The proposed system is implemented in real-time. The proposed system shows accurate results in real-time.

1. INTRODUCTION

The ever-increasing energy demand and conventional grid dependency are the main reason for increasing electricity costs, and the rising energy bills are what consumers are concerned about. Switching to solar energy proves to be a prominent and reliable energy solution due to the series of economic benefits for 25-plus years.

Electricity is the most essential needs in the lives of everyone in this modern world. The energy consumption graph is rising from day to day, while energy resources are diminishing in parallel. For the generation of electricity, many numbers of sources are used to balance the lack of electricity. There are two prime sources to generate electricity: one is the conventional sources of energy and the another one is non-conventional sources of energy. Several carriers of the energy like nuclear fuels and fossil fuels too are utilized, yet they are not the renewable resources and these are said to be the non-conventional resources. In its broadest sense, solar power source plays a vital role in achieving the sustainable power source. Sun's rays serve as a significant source for the electricity generation by converting it into electric power and this application is conventional, which is known as the Solar Thermal Energy.

Alternative renewable energy sources have been gradually replacing existing ones. One of the most promising alternate energy sources is solar which is becoming increasingly more efficient and cheaper to install. With emerging solar technologies, experts calculated that the average energy derived from solar radiation can provide up to 10,000 times more than the world's current needs [1]. In many countries, generation of electricity based on solar energy, especially photovoltaic (PV) cells, is being promoted with incentives for utility scale energy generation. The global solar PV market has been growing with almost half of all PV capacity added in the past two years, and approximately 98% of current systems have been installed since the beginning of 2004 [2]. PV modules produce no greenhouse gasses during operation and relatively little during manufacturing, and do not require significant resources which must be imported from other countries. There are no complicated moving parts associated with the PV power generation. This results in a very low operating cost and maintenance. Also, it is freely available and abundant in nature.

In spite of the several advantages, PV technology faces various barriers which prevent its wide deployment. The major barrier is the initial cost of setup. In the US as of 2010, the average cost of solar energy was $211/MWh, while it was $95/MWh for coal generated power [3]. Also, solar arrays are low efficiency compared to the light incident on them. Performance analysis of a 342kW roof mounted PV array using 10 years of data showed the array operating with an efficiency of 7-9 percent [4]. Thus, to improve PV array output is to ensure that the array operates in optimal output conditions at all times. PV arrays once installed are expected to operate with minimal human intervention. Despite the fact that solar PV systems have no moving parts and usually require low maintenance, they are still subject to various failures or faults along the PV arrays, power conditioning units, batteries, wiring, and utility interconnections [5, 6]. Most of these faults remain undetected for long periods of time resulting in loss of power. This results in reduced uptime of the array and decreased PV efficiency. The energy generation is often affected by conditions such as irradiance, temperature (weather conditions) and the connection topology of the PV array, which determine its overall power output [7]. In order to improve power generation robustness and predict system conditions, fault detection and monitoring [8-11] methods have been proposed.

Especially for PV arrays, it is difficult to shut down PV modules completely during faults, since they are energized by sunlight in daytime. Once PV modules are electrically connected, any fault among them can affect the entire system performance. This means the PV system is only as robust as its weakest link (e.g., the faulted PV components). In a large PV array, it may become difficult to properly detect or identify a fault, which can remain hidden in the PV system until the whole system breaks down. Due to the widely distributed PV arrays and the massive amount of generated sensor data, acquisition, storage and analysis in the monitoring processes is also a problem. By replacing current ad-hoc methods of monitoring and fault detection, the efficiency of PV arrays may be increased while decreasing the net cost of electricity from PV sources. Current methods of fault detection are not reliable, are slow with more than 3 days of turnaround time, and rely on manual monitoring by technicians [12].

In most cases, remote facilities using manual monitoring methods such as panel by panel manual metering which is very time consuming [13]. This is prone to errors and takes a lot of resources and manpower for completion. Thus, PV array monitoring systems need to be automated for the processes of data monitoring, acquisition and storage. The family of technologies and protocols collectively known as the smart grid (smart PV array) offer an opportunity to change this: with increased monitoring and communication among PV array components, significant improvements in overall array power production may be achieved.

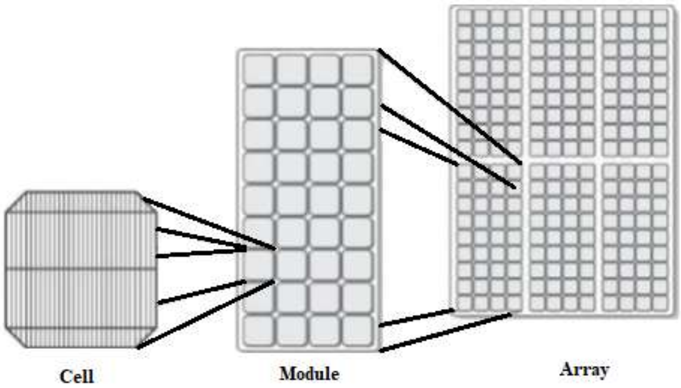

Fig. 1.1 Photovoltaic Cells, Modules and Arrays.

PV arrays convert solar radiation incident on them to electricity. They are composed of several components such as PV modules, inverters and electrical connections. The block diagram of a typical PV array is shown in Fig 1.1. Furthermore, PV is scalable and modular technology that can build a PV power plant by connecting a large number of PV modules in series and parallel configuration. PV modules in the same row are connected electrically in series to increase the generated voltage. This series arrangement is called a string. To form the array, several strings are connected in parallel thereby increasing the current generated. The DC power generated by the array is converted to AC by means of an inverter.

2. LITERATURE REVIEW

Improved measurement technology now includes automated meter reading and the ability to export energy measurement data [14]. An energy-metering chip, a PIC microcontroller, and a real-time clock IC make up the digital meter. Using the SIM 900 GSM module, the data is delivered to a remote server through a short message service (SMS). The server maintains track of the messages that come in.

The IoT and wearable computing create an advanced application in solar PV plant monitoring [15]. It has been reported that IoT has become a forceful medium to connect roads, streets, houses, and society. Hence, there is an immense possibility of using IoT and miniaturizing the computing system for a safe and cost-effective solar power distribution. Fast data acquisition from the field is an essential characteristic of monitoring devices. Raspberry pi is one of the best devices for data acquisition. Raspberry is an electronics device with built-in RAM, ROM with Digital and analog inputs, and an output pin for reading and writing data. The task computation speed of raspberry pi is 30-40 times faster than Arduino. The theme of the present work is a solar PV plant monitoring system by raspberry pi module and an intelligent display of daily usage of power production. An IoT-based system has been successfully integrated into the physical world with a computer system as far as solar PV plants' power production is concerned.

A control system with a digital signal processor (DSP) and human-machine interface (HMI) has been developed [16]. A practical application of DSP and HMI has been implemented in remote sensing applications using a proper interface. A solar PV module connected to a single-phase utility grid through an inverter is considered. A wireless sensor network architecture (WSN) is introduced for a reliable, error-free, and robust measurement of the parameters of solar PV cells. A ZigBee protocol based on the Duplex digital system has the IEEE standard for wireless personal area network (WPAN) based on the monitoring system.

In [17], a hybrid monitoring system has been adopted wherein both solar and wind power system monitoring is via Advance Virtual RISC based Microcontroller (AVR μC). Three parameters have been monitored: Wind speed, PV temperature, and solar irradiation. The proposed system could be a replacement for a thermometer, pyranometer, and anemometer. The advantage of the data acquisition method proposed is the possibility to communicate with the SCADA program. The applications described in the article provide a valuable understanding of environmental conditions to operate the hybrid power system effectively. The data acquisition system described in the article is checked instead of standard measuring instruments. The errors in the evaluation are below 5 percent.

The problems of PV monitoring are discussed [18]. The measurement and remote monitoring of PV parameters, such as open-circuit voltage, short-circuit current, electricity, and energy yield, are conducted. It is found that the lack of monitoring parameters is related to the conditions of the links, switches, and wire coatings that function as time mounts stability. It is expected that prolonged research will guide accelerated development tests to achieve a more comprehensive PV system.

In this study [19], the authors discuss the assessment of grid power efficiency in small-sized photovoltaic and low voltage networks. The Power Quality Monitor System (PQMS) is designed to conduct the evaluation. The 200ms data are stored on the server for four months. The PQ database provided by the PQMS enables a comprehensive examination of PV's effects on the local channel.

A study is done [20] on monitoring and manipulating the data and controlling the operation of a solar PV system. This proposed innovative system function is reported to realize in real-time. In this paper, the author addresses the solar panel problems related to inflexibility, poor manageability, mean time to repair, and difficulty in maintenance. The intelligent system's practical design and development are proposed to monitor, control, and administer the solar photovoltaic (PV) system to overcome the issues. The intelligent integration is made possible by fusing the concepts of IoT, machine-to-machine (M2M) based technology using IPV6 over a low-power personal area network (6LowPAN) and a wireless sensor network. This system helps monitor solar energy production in terms of voltage and current with accuracy in three decimal places. The machine-to-machine technology allows the online control of solar PV systems. Hence, an automatic setting for panel rotation towards the sun in receiving maximum radiation intensity could be remotely controlled. Real-time data saving is possible, and data can be saved using cloud computing and IoT techniques.

The focus is on the DG agents, grid agents, and Mu agents, according to Purusothaman, SRR Dhiwaakar, et al. [21]. Distributed energy resources (DERs), load, storage, and grid agents are examples of DG agents. The Mu agent serves as a conduit for communication between the DG and higher-level agents such as the control agent. An Arduino microcontroller was used to implement the system.

3. PROPOSED SYSTEM

The proposed work has two submodules, i.e., solar panel parameter monitoring and fault detection in solar panel using machine learning algorithm.

3.1 Solar panel parameter monitoring

The Block diagram of the proposed system is shown in Fig.31.

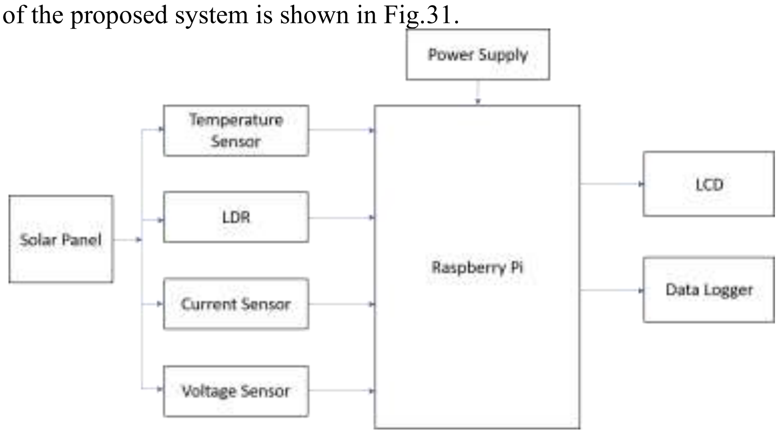

Fig.3.1. Block diagram of the proposed system

In this system, Raspberry pi is the main component. The temperature sensor is mounted on the solar panel to measure the temperature at the current time. The LDR is used to measure the light intensity. A current and voltage sensor is used to measure the solar panel's output current. The Raspberry Pi monitors these parameters. The RTC is used to get the accurate timestamp of the time. The data logger system stores the data in the raspberry pi's memory card, which shows all the temperature, light intensity, current, and voltage at a particular timestamp.

3.2 Fault detection in solar panel using machine learning algorithm

The solar panel parameters i.e., Temperature, Current and Voltage are considered for the detection of the fault in the solar panel. The faulty reading in the any of the parameter decide the fault in the solar panel. The Machine learning algorithm i.e., Support Vector Machine (SVM), K-Nearest Neighbor (KNN) and Gradient Boosting (GB). The dataset sample for the fault detection in solar panel using machine learning algorithm is shown in Table 3.1. It consists of Temperature, current and voltage parameter with lable. The lable ‘0’ indicates the non-faulty sample while label ‘1’ indicates the faulty sample.

Table 3.1. Dataset sample for fault detection in solar panel using machine learning algorithm

Temperature	Current	Voltage	Label
37.22342857	3.905859375	32.20703125	0
37.22342857	3.905859375	32.20703125	0
37.22342857	3.905859375	32.20703125	0
37.22342857	3.905859375	32.20703125	0
37.22342857	3.905859375	32.20703125	0
37.22342857	3.905859375	32.20703125	0
37.22342857	3.905859375	32.20703125	0
1.562881563	0.103125	422.4	0
0	0.000805664	3.3	1
0.012210012	0.000805664	3.3	1
0.012210012	0.000805664	3.3	1
0.012210012	0.000805664	3.3	1
0.012210012	0.000805664	3.3	1
0.012210012	0.000805664	3.3	1
0.012210012	0.000805664	3.3	1
0.195360195	0.012890625	52.8	1
0.195360195	0.012890625	52.8	1
0.195360195	0.012890625	52.8	1

The machine learning algorithm used for classification of the faulty and non-faulty readings of the solar panel is explain in detailed below.

4. RESULTS

In this section, the results of solar panel parameter monitoring and fault detection in solar panel using machine learning algorithm is presented.
The hardware interfacing diagram of the proposed system is shown in Fig. 4.1.

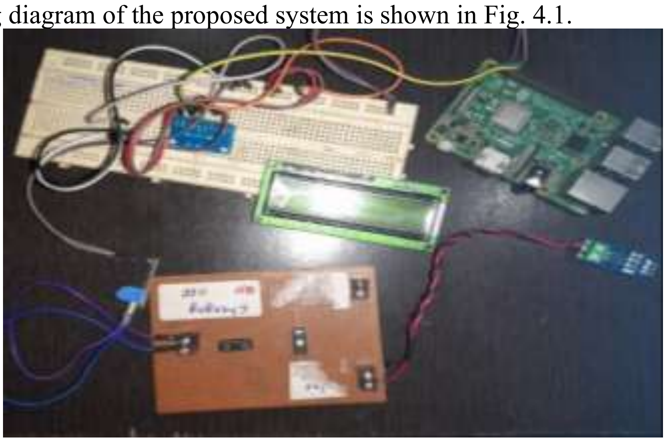

Fig.4.1: Hardware interface model

The proposed system is built using raspberry Pi 3B+, current sensor, Voltage sensor, Light intensity sensor. The Current sensor is connected in series while voltage sensor in parallel. The light intensity sensor measures the light intensity of the environment. The values of sensor are shown on the LCD as well the data log is created and save into the memory card.
In the following section the results of the fault detection in solar panel using machine learning algorithm is presented. This approach is implemented using python language and scikit-learn library. The database of two-month reading is considered to train the machine learning model. The whole dataset is split into training and

validation. 80% of the whole data is taken for the training while 20% data is taken for validation purpose randomly. The accuracy of the SVM, KNN and gradient boosting algorithm for fault detection in solar panel is tabulated in the Table 4.1.

Table 4.1. Performance of machine learning algorithm for fault detection in solar panel

Algorithm	Parameter	Accuracy
SVM	Kernel =rbf	0.8110
	Kernel=polynomial	0.6635
	Kernel=sigmoid	0.7972
KNN	K=3	0.9585
	K=5	0.9539
	K=7	0.9539
GB	-	0.9815

The graphical analysis of the performance of the machine learning algorithm for solar panel fault detection is shown in Fig. 4.3.

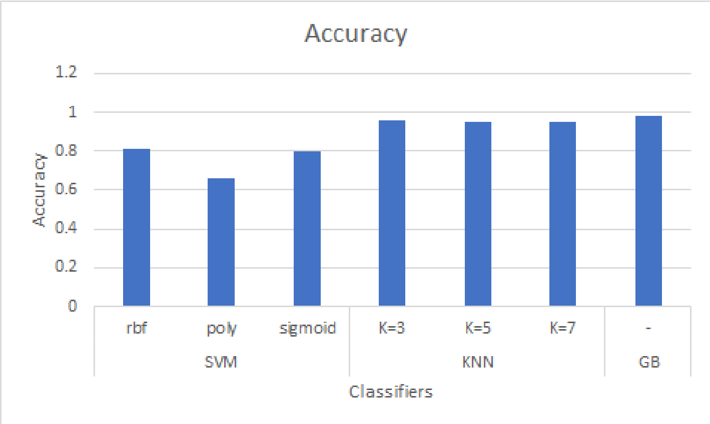

Fig.4.3 The graphical analysis of the performance of the machine learning algorithm for solar panel fault detection

From the Table 4.1 and Fig. 4.3, it is observed that the performance of the gradient boosting algorithm for classification of fault in solar panel is better than the SVM and KNN algorithm.

5. CONCLUSION

One recommended method of lowering environmental effects is to use Renewable Energy technology. Because of the frequent power outages, renewable energy must be used and monitored. The user is guided through the examination of renewable energy use through monitoring. This method is economical. The system all measures the voltage, current temperature, and light intensity. Raspberry Pi is used to implement the system. The data logger system is also implemented in this system. The proposed method is implemented in real-time. The proposed approach shows accurate results in real-time. The machine learning based approach for fault detection in the solar panel is presented. The input to the system would be voltage, current and temperature while output would be system fault or not. The performance analysis of the proposed system shows that the gradient boosting algorithms shows an accuracy of 98.50% which is better than the SVM and KNN algorithm.

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