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Development of Model for Estimation of Solar Panel Dust Accumulation

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Abstract— The Internet of Things (IoT) has evolved in use as a result of recent technical advances, and it is now a fundamental aspect of daily life. There are several possibilities for combining IoT-based solutions with photovoltaic (PV) renewable energy-based systems to increase generating capacity and minimize energy losses in power production. Energy losses in PVs can be caused by a variety of sources. This research focuses on the photovoltaic energy losses caused by dust accumulation. The purpose in this scenario is to make clever use of the IoT framework. The system is constructed utilizing a modular design approach. Each module has a front-end controller that is used to digitally represent the state of the PV panel in question. Real-time recording of. [?]

Index Terms: Photovoltaic, Embedded Processing, Automatic Dust Disposition Estimation, Decision Support, IoT & Cloud.

I. INTRODUCTION

Over the past ten years, there has been an upsurge in the use of photovoltaic (PV) solar modules. The conversion of these breakthroughs from large-scale laboratory models to small-scale applications have been accomplished successfully. The commercial production and sales of PVs have greatly expanded as a result of this accomplishment. PVs are now used in applications other than homes or off-grid ones. They are also used in mega-scale power plants, which produce electricity not just for local governments but also for entire cities all over the world. India plans to add 60 GW by the end of 2022, based on statistics and prior experience [6]. Considering the subsidies that are available, PV-based energy generation is generally much more cost-effective and affordable. India's government has something to give. The majority of nations' most recent laws firmly promote the use of PV-based renewable solar energy systems. It holds true, particularly for advanced smart cities. Despite the benefits already mentioned, there are several drawbacks that affect how well PV-based energy sources function as a whole. The main ones include dust buildup [4], [5], and a low tolerance for overheating. They decrease the output power of photovoltaic solar cells by decreasing their efficiency.

II. OBJECTIVE AND PROBLEM STATEMENT

The detection of surface dust is an important factor to take into account. Many studies have been conducted recently on the detection of dust on solar panels for soiling not only the dust but also the surface dirt like plant products, soot, and bird droppings, and also the region with the highest sunlight annually are the desert regions. The main cause of a decrease in efficiency in a desert region is the lack of rainfall, which makes it more challenging to remove the settled down dust on the panels. Based on solar generating records, it is intended to estimate the amount of dust on the panels and identify the root of the reduced efficiency.

III. MOTIVATION

The amount of renewable energy being used on a daily basis is increasing in order to supply clean, sustainable electricity. Solar energy usage has dramatically increased in recent years. Numerous elements, including moisture, dust, humidity, and shadow temperature, have an impact on the panel's output. Finding the proportion of dust accumulation in the solar panels is necessary to determine the cause of the performance issue. By calculating the proportion of dust, it is possible to draw the conclusion that as solar panel performance declines, dust accumulation increases.

IV. BACKGROUND STUDY

The performance of PV panels can be impacted by a number of factors, such as a drop in power output caused by dust deposition. The solar radiation density, the size, quantity, and mass of the dust particles, as well as the type of glass used to cover the PV panel surface, all have a significant impact on the power output of a PV. Surprisingly, the more sunlight is blocked from reaching the PV panel surface the smaller the dust particles are. Additionally, sand, ash, soil, and silica are just a few of the contaminants that can build up on a PV panel and reduce its electrical performance. The particles' physical properties vary Depending on the local environmental factors, such as the air, humidity, and temperature, substances have different chemical and physical properties.

Numerous research has been done to examine and study the impacts of dust accumulation. The majority, if not all, concur that dust lowers a PV panel's efficiency. An experi mental investigation in [2] examined the electrical

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performance of dust-covered PV modules. It takes into account a variety of factors, including the size and design of the PV module system, radiation levels, and operational methods. According to authors, dust does affect how well PVs perform electrically. Another study that looked at the effects of the environment on the performance of PV panels came to the conclusion that dust deposition results in a 4.4% daily energy loss over the course of a year [3]. Additionally, it has been established that daily energy loss might exceed 20% in regions that experience prolonged drought. Additionally, authors in [1] and [5] have determined that the site where the system is installed is a factor in the reduction in the amount of PV generated power.

Saudi Arabia is one of the nations most affected by sandstorms despite the fact that Middle Eastern countries are more likely to experience them due to their expansive sandy undeveloped terrain. The quantity of electricity generated is reduced when dust builds up on the surface of photovoltaic modules because it reduces the amount of sunlight that the PV cells can absorb and creates a shadowing effect. As a result, electrical energy production decreases as dust deposition increases [5]. A construction site, an industrial region, solid material particles, etc. are some sources besides sandstorms.

This study discusses the effectiveness and efficiency of PV systems in regard to dust. A customized algorithm automatically locates and identifies the solar panels that need to be cleaned. The identity of the affected solar panel will be communicated to the maintenance company via emails in real-time in order to assist effective cleaning and repair of the affected solar panels. Additionally, for later analysis and decision-making, the condition of the solar panels is recorded on the cloud. The remaining sections of the article are the materials and methods part, the findings section, and the conclusion section.

V. PROPOSED METHODOLOGY

The proposed system is designed on the basis of a modular approach. The main module blocks are displayed in solution architecture and portrayed in the accompanying subsections. We are developing a system to avoid/reduce the effects of dust/dirt on solar PV panels since it degrades the efficiency of solar panels to a great extent. The main parameter of the Solar panel is VOC i.e the open circuit voltage which turns out to be 48 V (Nominal). The Analog Input signal is fed into the RTU via the Solar panels and the RTU helps to communicate between the automation devices using MQTT (GPRS). Finally, the Data from the cloud is displayed/published on the PC through the internet. To simulate different levels of depositions, the study was done on 5 scenarios as below: 1. 20 % of dust has settled on the solar PV panel. 2. 40 % of the dust has settled Similarly, 3. 60 % - Translucent visibility. 4. 80 % - Foggy Visibility. 5. 100 % - Opaque Visibility. (Almost no penetration of light).

Apparatus: 1. Solar PV panel 2. RTU 3. Cloud Server 4. PC 5. Sensors and Actuators (Irradiation, Wind speed, Ambient temperature).

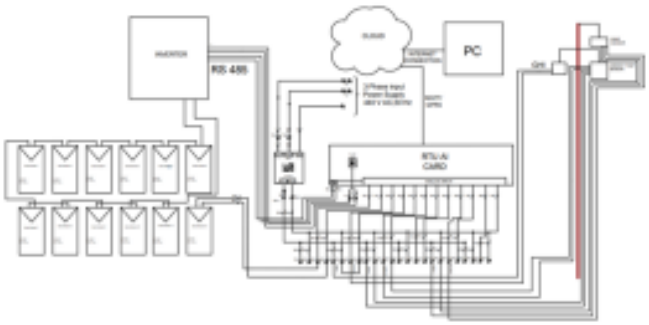

Figure 1. Methodology Diagram

Real-time monitoring of Open Circuit Voltage of Solar Panel, Solar Irradiation, Ambient Temp, Module Temperature Wind Speed to estimate dust composition.

For monitoring the degradation effect caused by the settling of dust on solar panels we have incorporated an IOT based RTU. To Measure the Weather Monitoring parameter which will be the reference parameter to estimate the Dust composition level, we have installed the weather sensors i.e. Solar Irradiation Sensor, Module Temperature, Ambient Temperature with Radiation Shield Wind Speed.

IoT Base RTU will have Analog inputs through which the Open Circuit Voltage of the Solar Panel–VOC, Solar radiation (w/m2), Module Temperature, Ambient Temperature Wind Speed Sensor's Analog signals are connected for measurement. All Weather sensors will be Powered up through Single Phase SMPS 24VDC.

RTU will have the GPRS Wi-Fi connectivity to securely connect using TLS SSL with a head-end cloud SCADA server. RTU will periodically push the Solar Panel Open Circuit voltage –Voc as well as weather station sensor data over the head end cloud SCADA Server. The dust Estimation mathematical model will be executed on the head-end cloud SCADA server. Based on the received data of Open Circuit voltage weather station parameters, a mathematical model will estimate the dust composition of solar power plant performance.

A. SENSORS USED

Solar irradiation (W/m2):- Economical but robust and reli- ˆ able solution for measuring solar irradiance levels, particularly for monitoring photovoltaic systems. Module Temperature:- The module temperature sensor is used by PV plant operators to know the temperature of the modules installed in the array. The module temperature sensor converts this reading into a voltage signal. This signal is sent back to the monitoring device. For the system operator, it is important to know the system's performance. The module temperature sensor will help to enhance kWh performance by

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ensuring reliable access to all necessary data. Ambient Temperature (Celsius):- Ambient temperature sensors can help you keep track of environmental factors such as temperature, humidity, and airflow in your data center so you can avoid downtime.

Wind Speed(m/s):-A wind speed sensor is a device used for measuring the speed of the wind The wind generated by the airflow drives the top three wind cups to rotate, and the central axis drives the internal sensing element to generate an output signal, which can be used to calculate the wind speed.

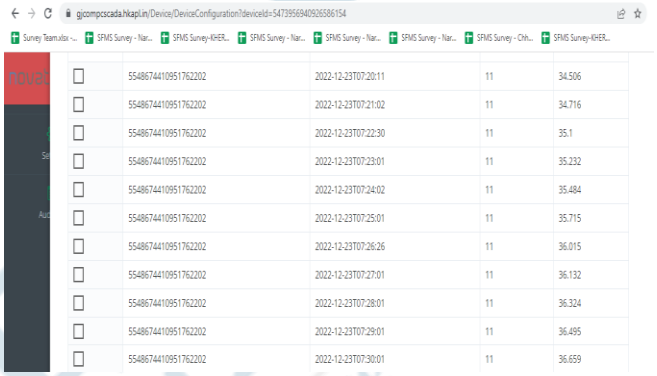
Figure 2. Weather Station

B. EXPERIMENT

The continuous monitoring process on the 325 W Solar PV module is carried out with the objective to find out the Solar radiation, Open Circuit Voltage, Wind Speed, Ambient Temperature, etc. These Parameters are generally affected by dust deposition on solar panels hence it is of utmost importance to measure the following. I have implemented an IOT-based RTU to monitor the deterioration effect brought on by the settling of dust on solar panels. Further installed weather sensors, including the Solar Irradiation Sensor, Module Temperature, Ambient Temperature with Radiation Shield, and Wind Speed, to measure the weather monitoring parameter that will be used as a reference parameter to estimate the dust composition level. IoT Base RTU's analog inputs will be used to link the analog signals from the solar panel's open circuit voltage (VOC), solar radiation (w/m2), module temperature, ambient temperature, and wind speed sensors for measurement. The Single Phase SMPS 24VDC will be used to power up all-weather sensors. RTU will have GPRS/Wi-Fi connectivity so that it may safely connect to the head-end cloud SCADA server using TLS/SSL. The weather station sensor data as well as the solar panel open circuit voltage (VOC) will be periodically pushed by RTU through a head-end cloud SCADA server. The head-end cloud SCADA server will be used to run the dust estimation mathematical model. A mathematical model will evaluate the composition of the dust and the performance of the solar power plant using the Open Circuit voltage and weather station parameters as input.

VI. RESULT AND DISCUSSION

A. LIVE-DATA MONITORING

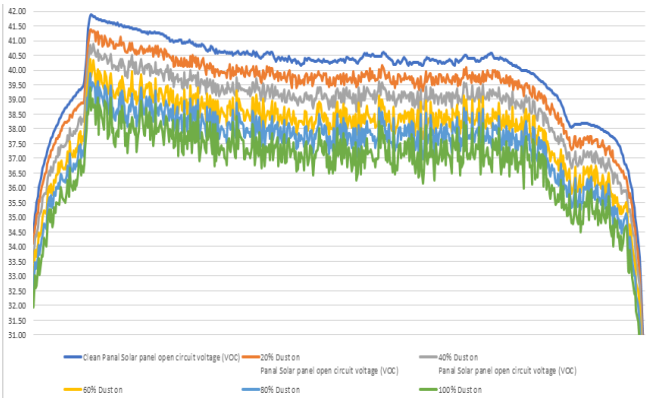


5548674410951762202	2022-12-23T07:20:11	11	34.506
5548674410951762202	2022-12-23T07:21:02	11	34.716
5548674410951762202	2022-12-23T07:22:30	11	35.1
5548674410951762202	2022-12-23T07:23:01	11	35.232
5548674410951762202	2022-12-23T07:24:02	11	35.484
5548674410951762202	2022-12-23T07:25:01	11	35.715
5548674410951762202	2022-12-23T07:26:26	11	36.015
5548674410951762202	2022-12-23T07:27:01	11	36.132
5548674410951762202	2022-12-23T07:28:01	11	36.324
5548674410951762202	2022-12-23T07:29:01	11	36.495
5548674410951762202	2022-12-23T07:30:01	11	36.659

The data accessible on the SCADA software was viewed and evaluated for the two situations of dust deposition on the solar panels, namely 20% and 40% dust accumulation.

		Clean Panal	20% Dust on Panal	40% Dust on Panal	60% Dust on Panal	80% Dust on Panal	100% Dust on Panal
Time stamp	Solar Irradiation (W/m^2)	Solar panel open circuit voltage (VOC)	Solar panel open circuit voltage (VOC)	Solar panel open circuit voltage (VOC)	Solar panel open circuit voltage (VOC)	Solar panel open circuit voltage (VOC)	Solar panel open circuit voltage (VOC)
2022-12-23 7:20:11	7.87	34.51	34.13	33.48	32.85	32.49	31.94
2022-12-23 7:22:30	8.99	35.10	34.68	34.27	33.85	33.46	33.01
2022-12-23 7:23:01	10.12	35.23	34.77	34.39	33.88	33.24	32.61
2022-12-23 7:24:02	10.12	35.48	35.08	34.36	33.67	33.28	32.67
2022-12-23 7:25:01	11.24	35.72	35.16	34.68	34.08	33.67	33.25
2022-12-23 7:26:26	12.37	36.02	35.56	35.02	34.48	34.05	33.59
2022-12-23 7:27:01	12.37	36.13	35.54	35.10	34.37	33.75	33.06
2022-12-23 7:28:01	13.49	36.32	35.92	35.18	34.46	34.08	33.45
2022-12-23 7:29:01	14.62	36.50	36.06	35.38	34.71	34.29	33.71
2022-12-23 7:30:01	15.74	36.66	36.10	35.67	35.01	34.35	33.67
2022-12-23 7:31:01	15.74	36.81	36.32	35.77	35.23	34.76	34.29
2022-12-23 7:32:01	16.87	36.95	36.45	35.82	35.20	34.72	34.19
2022-12-23 7:33:01	17.99	37.08	36.54	35.82	35.12	34.61	34.00
2022-12-23 7:34:01	17.99	37.21	36.80	36.12	35.45	35.05	34.48
2022-12-23 7:35:01	19.12	37.34	36.89	36.38	35.87	35.44	35.00
2022-12-23 7:36:01	20.24	37.45	37.07	36.56	36.04	35.68	35.26
2022-12-23 7:37:01	22.49	37.55	37.06	36.45	35.84	35.37	34.85
2022-12-23 7:38:01	25.87	37.67	37.27	36.69	36.12	35.74	35.26
2022-12-23 7:39:01	29.25	37.76	37.28	36.52	35.77	35.32	34.67
2022-12-23 7:40:01	31.5	37.85	37.41	36.64	35.88	35.47	34.81
2022-12-23 7:41:01	32.62	37.93	37.48	36.87	36.26	35.83	35.32
2022-12-23 7:42:01	34.87	38.01	37.55	36.86	36.19	35.75	35.16
2022-12-23 7:43:01	37.12	38.09	37.67	37.04	36.43	36.03	35.50
2022-12-23 7:44:01	38.25	38.17	37.66	37.05	36.45	35.97	35.46
2022-12-23 7:45:01	40.5	38.24	37.76	37.37	36.83	36.15	35.47
2022-12-23 7:46:01	42.75	38.31	37.74	37.13	36.53	35.98	35.41

As per the data analysis, the output of Solar PV was reduced proportionally for both scenarios.



The relevant soft tags are framed in the SCADA software for the computation of the data received from the RTU for the future prediction of solar generation and appropriately, alerts for the maintenance crews for the field trouble.

VII. CONCLUSION AND FUTURE WORK

The method was proposed in order to identify the dust accumulation on the photovoltaic panels. The experiment is done on the field with help of apparatus:- 1.Solar PV panel 2.RTU 3.Cloud Server 4.PC 5.Sensors and Actuators (Irradiation, Wind speed, Ambient temperature) The real-time data has been obtained for the above-mentioned sensors, Further, Another consideration is to use cloud-based logged data to forecast system behavior using advanced machine learning algorithms.

VIII. ACKNOWLEDGEMENT

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