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Smart Solar Panel Cleaning System Using IoT

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Abstract---In recent days demand for electricity has increased, gradually along with the development of technology especially in the field of E-vehicles. Due to gradually increasing the electricity demand people started moving to the field of renewable energy sources. Among the renewable energy sources solar PV modules are mostly preferred, nearly 70% consumption of renewable energy sources. The accumulation of dust particles on the solar PV modules can reduce the power supply production from the module. In order to clean the panel effectively, here employing a cleaning system using Node MCU ESP8266 which has an inbuilt wi-fi module to monitor the system using IOT.

Keywords: - Solar Panel, Node MCU ESP8266, E-vehicles, Dust Particle, Internet of Things, Arduino Cloud, API-client.

I. Introduction

In solar modules mostly the obtained power will not be constant because of the dust particles, ambient temperature, intensity and insolation of the light. The ambient temperature, intensity and insolation of the light are the natural causes to reduce the power production and there are no other ways to rectify it. But the settling of dust on the solar panel is man made mostly due to pollution. The dust particles can be removed by cleaning the panel by using water wash or by wiper manual manner. In the smart solar panel cleaningsystem the removal of dust particles will happen through the process of reduction in voltage supply in normal temperature standard condition with the help of Node MCU ESP8266 and the panel cleaned data along with the time stamp are stored in a database. The dust accumulated on the solar panel reduces the panel voltage nearly up to 50%.

II. Solar PV module

A solar PV module which converts the light energy from the sunlight directly to the electric energy or

electricity (D.C) which is the essential component. The solar PV modules are connected in series or parallel depending upon the need of the current, voltage and power needed for the load.

III. V-I & P-V characteristics of a solar cell

Usually the V-I characteristics of a solar cell have been monitored to identify the problems. In V-I characteristics of a solar cell the voltage has been increased logarithmically while the current has been increased linearly.

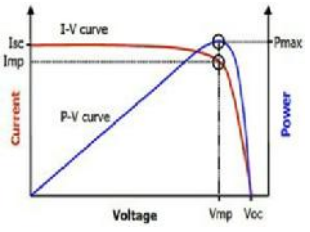

Figure 1.V-I characteristics of a solar panel.

IV. Components needed

- Gear Motor
- Solar Panel
- Panel stand
- Voltage Sensor
- Wiper
- Wheel
- NodeMCU (ESP8266 Wi-Fi development board).
- Ultrasonic Sensor
- Humidity Sensor
- Temperature Sensor
- Solar PV Emulator
- Roller Brush
- Power Supply or Battery
- Arduino Cloud

A. Gear Motor

It consists of a gearbox and electric motor in a combination. The motor along with the gear reducer system which is beneficial for the applications of low speed with high torque. The specifications of the motor are 12 V Dc with 100 rpm speed along with the 125gram of weight of load current of 300 mA and no-load current 60 mA. It has stall torque of 1.5 Kg/cm.

B. Solar panel

The solar panel which is made up of silicon dioxide coating converts the solar energy into electric energy. The solar panel specifications at standard temperature constant of 25degree Celsius cell, 1000 W/m^2 along with the AM 1.5. The panel has the Maximum Power (Pmax) of 10Watts, Maximum Power Voltage (Vmp) of 17.0V, Maximum Power Current (Imp) of 0.59 A, Short Circuit Current (Isc) of 0.63 A, Open Circuit Voltage (Voc) of 21 V and the maximum System Voltage of 600 V. The single panel has a length of 30 cm and the width of 24.5 cm.

C. Panel stand

For the solar panelgenerally, we need a stand to hold it. The solar panel stand is made up of stainless steel with a length of 84 cm and a width of 30 cm. The stainless-steel material has a width of 10 cm and both sides 5cm are welded for the efficient movement of the wheel. The panel stand has a frame in the bottom with a square shape of 5cm. The frame at one side will be framed with a height of 23 cm at one side and 30 cm at another side with the mild steel with the mud filled inside the hole. The material of the stands was painted in order to protect the material from corrosion.

D. Voltage Sensor

The value of the voltage is detected by the use of a voltage sensor. Based on the voltage divider the measurement has to be done. Here the voltage sensor used for the measurement of DC. The reduction of the voltage from panel value details are updated by the voltage sensor. The details of the reduction voltage by the panel is necessary for the purpose of the cleaning. The voltage of the panel may also be reduced to some unwanted circumstance condition such as weather conditions, humidity etc.

E. Wiper

The wiper used for cleaning purposes. There are two modes of cleaning purpose namely the clean by water and the clean by air pressure. The wiper materials should not scratch the solar cells and it is also efficient to remove the dust particles. The wiper must be a soft material around the metal piece. The inner part of the material should have hard fibre material between the soft & metal pieces and the outer part should be spongy for effective cleaning. So as to protect the metal from rusting and corrosion. The water cleaning is employed here.

F.Wheel

The wheel used for the project GR (Generic Robodo) Electronics X wheel which is mostly used for the gear motor. The wheel used the smooth movement of the roller brush for the cleaning purpose. The wheel moves in the part along the 5 cm in between space as provided in the panel stand length. The movement wheel should be smoothly in accordance with the coordination of a roller brush.

*F. Node MCU (ESP8266 Wi-Fi development board***)**

It is a platform of open source mostly ESP8266 based in which the objects are connected and using the Wi-Fi modules and the Wi-Fi protocols its data are transferred. It is mostly used in the IoT platform. The node MCU has so many pins namely Ground pin for grounding purpose,I2C pin of 100 kHz frequency where I2C sensors are connected, GPIO pins where used the functions are assigned to other pins, ADC channel used for ADC functions are implemented where SAR ADC is embedded with 10-bit precision,UART pin used to communicate up to a speed of 4.5 Mbps, SPI pins which has a SPI format transfer for 4 modes of timing with 80MHz divided clocks along with FIFO 64 bytes,SDIO pins used for SD cards interfacing of 50MHz with 4 bit, PWM pins for adjusting frequency range from 100 HZ to 1kHZ and control pins for the purpose of the enabling, reset and wake with the EN, RST and WAKE internal pins respectively.

G. Ultrasonic Sensor

Usually, the ultrasonic sensor is used for the purpose of the distance measurement with the ultrasonic sound waves.Here the ultrasonic sensor is used the distance measurement of the wiper while in the movement for the cleaning purpose to identifying in case of there is a stoppage of the roller brush in the solar panel in between while cleaning the panel.

H. Humidity Sensor

The humidity sensor is to detect the humidity in the surrounding with the help of the air temperature. Thermal, resistive and capacitive are the types of humidity sensor. The RH (Relative Humidity) of the air or water content in the air can be determined. The humidity sensor also plays a major role in the cleaning process.

I. Temperature Sensor

Thetemperature sensor is usually used to measure the temperature around the surrounding area. If there is a decrease in temperature is mostly due to the humidity or else night time. The temperature sensor indicates night time as per the instructions given by the data set of the standard temperature of the morning to night time of every day.

J. Solar PV Emulator

The solar PV emulator is used to sense the solar irradiance for the particular location. The sensed solar irradiance value compared with the monthly data of solar irradiance value. The irradiance value should be mostly a round-off or the nearest value to the monthly value or else the sun is surrounded by the cloud.

K. Roller Brush

The roller brush plays an important role in the cleaning processes. The roller brush moves for cleaning the solar panel. the movement should be in an effective manner. The roller brush receives the information from the IoT platform whether to clean the panel or not and cleans according to the information.

L. Power Supply or Battery

The power for the gear motor is supplied by the battery or power supply. The power supply 12 V battery is connected to the motor. The battery is rechargeable and it is recharged from the solar panel. The battery is connected to a switch which is to be turned on when it receives from the Node MCU.

M.Arduino Cloud

The cloud platform is chosen for transmitting the data of voltage, humidity, temperature and solar irradiance to shows its live update using Node MCU.

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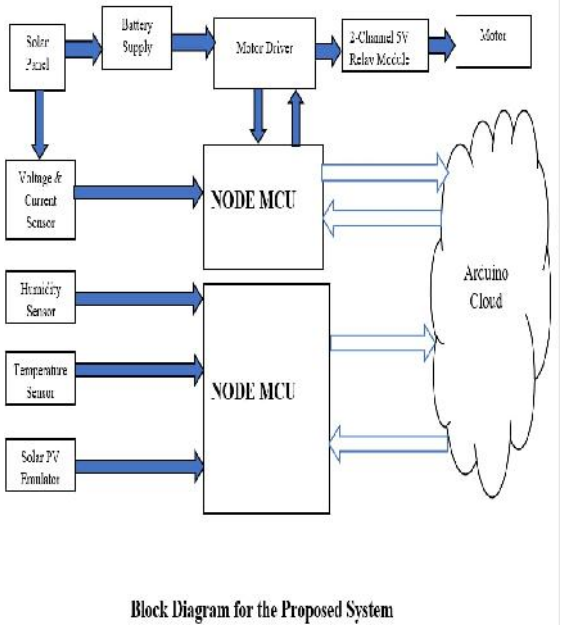

Figure 2. Block Diagram

V. Factors taken into consideration for cleaning

Generally, there are some factors which are to be taken into the consideration like that here also for the cleaning the solar panel we are taken into consideration of the some of the factors namely

- Solar irradiance
- Voltage
- Partial shaded condition
- Humidity
- Night Time
- Extreme Temperature

A. Solar Irradiance

Solar radiation is the first & the foremost factor which has been taken into account because the solar radiation is different for different times, different seasons and also has changes in a minor difference day by day. Here we are accounting the changes of solar radiation for 10 days once. If the solar radiation has minor changes in value, its fixed value is taken into account. If the solar radiation has a major change in value, it is not to be taken into consideration. The solar radiation also has to be changed hourly and also by location.

B. Voltage

Voltage is an active source element. In the panel the voltage produced by the single panel is considered mostly. The voltage reduction happens due to the dust accumulation of the solar cells, partial shaded condition and also the climatic conditions. Here the cleaning of the solar system is done with the voltage reduction. The task of climatic conditions in the reduction of voltage will be overcome by the humidity sensor whereas the process of the partial shaded will be overcome by the MPPT algorithm timestamp for hourly the shaded part in the solar panel installed part.

C. Partial Shaded Condition

In the Solar PV Module under the partial shaded condition due to some natural conditions such as shaded parts will occur and it will cause total reduction in the output power. The partial shaded condition will have oscillating power depending on the shaded part. So, the maximum power point tracking under the shaded part has been tracked in order to give the efficient and maximum power.

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D. Humidity

The humidity also plays a major role in the reduction of the voltage. To detect the humidity or moist condition in the surrounding area the humidity sensor plays an important role. If there is no humidity or moist condition of the air the reduction happens mostly due to dust particles.

E. Night Time

The sun sets in the evening and therefore we don't get solar energy in the night time. The night time is also detected by the temperature sensor as per the data set. At night-time is mostly when we use backup power from the battery as the extra energy from the daytime is stored in the battery. So, we need an essential back up battery according to the load needed at night time.

F. Extreme Temperature

The extreme hot temperature during the month of march to July could be a decrease in the voltage and power production because the energy from the solar cell has been dissipated in the form of heat. The dissipated heat can lead to damage of solar cells or even leads to burning of the solar panel. It could be avoided by the cooling of the solar panel.

VI. Factors which are not taken into account for cleaning

Usually some of the factors which are not to be taken into consideration for some factors. The factors which are not to be taken into account are namely

- Current
- Efficiency
- Fill factor
- Wind Velocity

A. Current

Current is also an active source element. In the panel the current produced by the single panel is considered mostly. The reduction in current value happens due to the dust accumulation and also one of the foremost factors is heat dissipation or very low load on the output side. So, only the term current is not taken into account as one of the factors while cleaning the panel.

B. Efficiency

Hence efficiency is the term which depends solely on the output term by its input term. In this case we are going to consider power as the term. The power varies up on the load and the remaining energy produced in the panel will be stored in the battery systems. So,only the term current is not taken into account as one of the factors while cleaning the panel.

C. Fill Factor

The quality of the solar cell is measured by the fill factor. Fill factor is the ideal solar cell; the VI characteristics of a solar cell are square in shape. But usually, we get only the bend shape curve fill factor is directly proportional to the term current and hence the term current is not taken into account. So, the term fill factor is also taken into account for the cleaning for the solar panel system.

D. Wind Velocity

The dust particle accumulation on the solar system most of the time is due to the blowing of wind with a higher velocity. The factor of wind velocity is not taken into consideration for the cleaning purpose. Hence the measurement of the wind velocity and the dust particles accumulated is to be done for the particular velocity. In case of high wind velocity, it can even cause damage to the panel.

VII. Essential Need of Solar Panel Cleaning System

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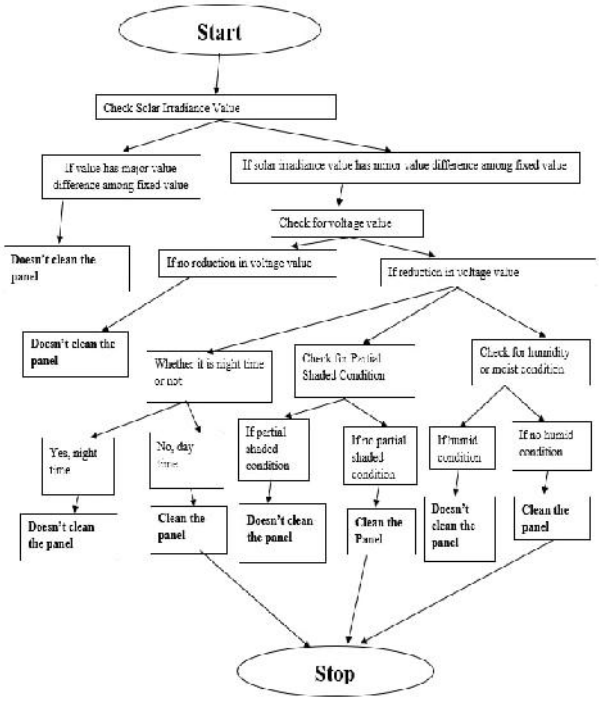
Nowadays the power demand increases along with the technology. People feel comfortable along with technology. The medieval technology such as fossil fuel for vehicles and power production. The fossil fuel has been also very small in amount and it's starting to be depleted now because it's a non-renewable source of energy. Because of the lack of the non-renewable energy resources people started moving towards the renewable sources of energy. In the renewable source of energy, the wind energy, hydro energy, biomass for power production is not available for all days in a year. But solar energy is available 360 out 365 days in a year because from the sun only we get the solar energy. Nearly 60% of energy production in renewable energy will be produced from solar energy. In solar energy nearly 40% of energy for power production is wasted because of the dust accumulation of layers of the solar cell on an average. The dust particles are due to the air pollution mostly from the industries. Solar energy plays a major role after 5 years to withstand the demand of the power production. In order to withstand the demand, the solar panel cleaning system is an essential need. In the desert area the dust accumulation is due to the dust storm. The dust storm happens frequently and so we are using electro-standing waves to clean the panel.

VIII. Challenges in the cleaning process

- In the desert due to the sand storm, it is difficult to clean the panel frequently.
- In the hilly areas with increase in height the solar irradiance also increases but the temperature decreases.
- In the seashore due to the frequent land and sea breeze there will be changes in the solar irradiance value.
- In the case of the high wind velocity.



Flow chart of the smart solar panel cleaning system

Figure 3. Flow chart of the model

IX. Working of the cleaning system

In the proposed system the working is based on the IoT cloud system with the consideration of the above factors. The cleaning of the solar panel is based on the voltage reduction. The voltage reduction happens mainly due to the climatic conditions or the dust particle accumulations. The cleaning of the panel for the dust particles accumulated based on the voltage first needs to verify some of the conditions such as humidity, partial shaded condition and night time. If it's night time the temperature solar irradiance has a major difference in its value, with the help of the solar irradiance value and temperature value it doesn't clean the panel. If it's partially shaded then with the help of MPPT we can track it and by the detection of the MPPT algorithm the panel doesn't get cleaned. The cleaner is a roller brush with a water wiper. In case if some of the cells are dust accumulated mostly then the solar with the IoT open-source controls the gear motor to the particular area and wipes it very slowly. The roller brush is a sponge material and doesn't lead to damage to the cells in the

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panel. The cleaning of the panel is from one side to the other and from the other to the starting point by the movement and the movement is controlled by the gear motor. The gear motor movement can forward or reverse based upon the movement and the movement indication can be indicated on the IoT platform. If the movement of one side is forward and the other side would be reserved it leads to the expansion and this problem can be solved by the open source IoT platform and we can change the direction of the movement by controlling the IoT platform. The solar irradiance data for a particular location is taken from the website of solar radiation. It gives the solar irradiance for a particular location by choosing the location, it loads the latitude and longitude. After checking the latitude and longitude value processes the file and the file is processed once after it loads the monthly data of the solar irradiance, relative humidity etc. With the help of the PV Emulator, we are going to sense the solar irradiance value for the particular location. The sensed value is also mostly to the round-off or the nearest value to the monthly data value. If there is a change in the value it happens due to moisture or humidity conditions. If there is no solar irradiation value and the reduction in voltage happens is due to the dust particles accumulation. The dust particles accumulation happens mostly due to settling of it when there is no blow or else when there is a wind blow in the particular location. The Arduino Cloud Platform is used here to store the information of voltage, current and other essential parameter values. From the cloud platform the Node MCU receives information about the reduction of voltage value and checks the above conditions before it starts cleaning the panel. After verifying the conditions, if there is no problem with the condition then the reduction of this happens the Node MCU sends information to the cloud about the cleaning of the panel. The cloud makes the movement of the gear motor forward & reverse direction along the movement of the roller brush by rolling on the water wipe. After cleaning the panel it once checks the voltage if there is an increase in voltage after 10 minutes then the Node MCU sends information to the cloud that doesn't clean the panel and it doesn't panel. Most of the time the dust particles accumulate due to the blowing of the wind. In that time solar irradiance also decreases means there is a high wind velocity. The high wind velocity occurs rarely during the rainy seasons. In that time there is no wind blowing the dust particles are starting settling on the panel. The settling of the dust also decreases power production generally.

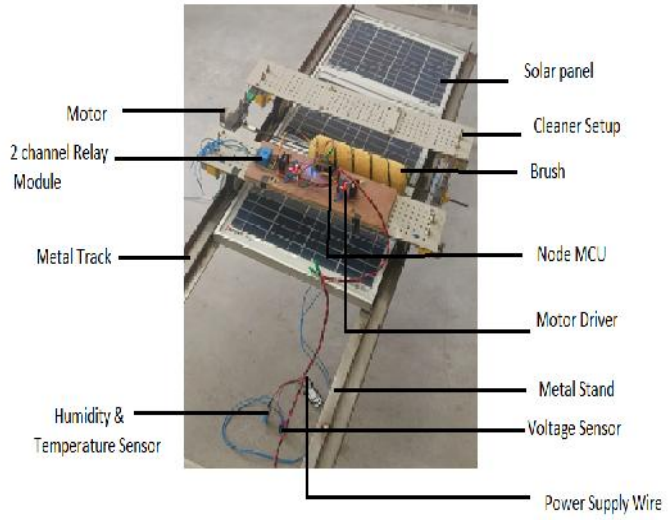

Figure 4. Working model

X. Result Analysis

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Figure 4. Graphical representation of Temperature Data

Figure 5. Graphical representation of Humidity Data

Figure 5. Graphical representation of Voltage Data

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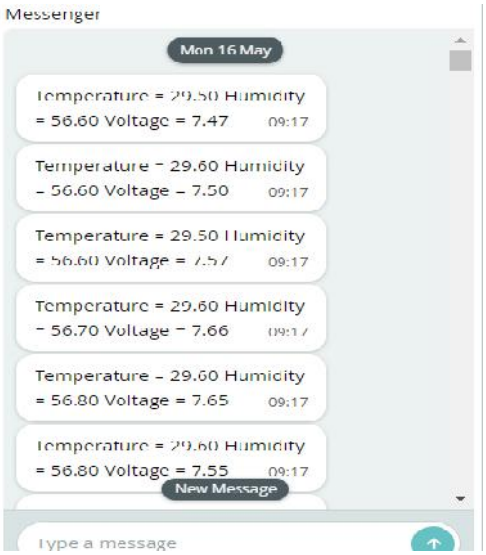

Figure 6. Messenger data

Day	Voltage	Temperatu	Humidity
1	7.55	29.5	56.66
2	7.41	29.6	56.7
3	7.08	29.7	56.8
4	7.17	28.3	56.8
5	7.28	28.99	56.8
6	7.3	29.9	56.7
7	7.55	29.7	56.8
8	7.19	29.4	56.2
9	6.99	27	55.7
10	6.88	26.77	55.6
11	6.15	27.77	55.4
12	6.34	27.8	55.5
13	6.32	27.5	55.5
14	7.11	28.66	56.7
15	6.2	25.9	55.1

Figure 6. Cumulative value of Voltage, Temperature & Humidity

XI. Conclusion

The smart solar panel cleaning system cleans the solar panel in an effective manner. It is a cost-effective method of cleaning the Panel. It cost nearly 17,040 for 30W panels. It can increase the power production of the panel nearly 40% . The solar cheapest manner of installing for power production in renewable sources and it can withstand the electricity demand in near future upto 25% when there is no availability of the non-renewable sources of energy.

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