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Smart Solar PV Soiling Loss Detection System

Nisha D, Preethi Remanciya G, Shivashree S, Vikrathi R
Dept. of Electronics and Communication Engineering
K. Ramakrishnan College of Technology (Anna University Affiliated), Trichy, India
nishadurairajilu05@gmail.com, preethiremanciya@gmail.com
shivashree37@gmail.com, vikrathiramaraj@gmail.com

Abstract : *Solar Photovoltaic (PV) Panels are commonly used to generate clean Renewable Energy. However, Dust Accumulation can cause a reduction in solar radiation. Manual testing and cleaning the panels at certain intervals may not be effective due to environmental factors. The aim of this project is to design a simple, low cost solar PV soiling detection and alert system. A LDR sensor is used to detect changes in Light Intensity. The analogue signal from the sensor is sent to the Arduino UNO, which compares the sensor reading to a threshold. The status of the sensors will be shown on the LCD. If the threshold has been exceeded then the system will alert the user by turning on the LED and Buzzer. This system can be used to monitor the change in readings. The simple, low cost and easy to implement prototype can be used for educational purposes and small scale solar monitoring. Further electrical measurements would be required to see how much the Photovoltaic has been affected by the dust.*

Keywords: Solar Photovoltaic Panel, Arduino UNO, LDR Sensor, Dust Accumulation, Light Intensity, LCD, Alert, Renewable Energy

I. INTRODUCTION

Solar Photovoltaic (PV) Panels are one of the most popular technologies for generating clean renewable electrical energy. Solar panels can be commonly found in residential buildings, industry, street lights and large solar farms due to their ability to convert solar energy directly into electrical energy. It is important that solar panels operate efficiently to meet the growing demand of renewable energy. The amount of electricity generated from the panels will depend on the amount of sunlight hitting the panels and how clean the surface is. A common issue with solar photovoltaic panels is soiling. Over time dust, sand, dirt and other particles can accumulate on the panels surface causing less sunlight to hit the photovoltaic cells. How dirty the panels become will depend on the weather conditions, environment and where the panels are located. This can lead to lower energy being produced however this can be overcome by regularly cleaning the panels. However, it may not be practical to constantly monitor the panels manually and also set cleaning times as not all locations will have the same amount of soiling. By monitoring the surface of the solar panels it can be determined whether they need to be checked. Traditional solar panels are monitored manually or regularly cleaned. This can lead to unnecessarily cleaning the panels or waiting until there is more soiling. Having a simple and low cost monitoring system can help give an indication as to when the light conditions are changing around the panel.

The aim of this project is to design a Low-Cost Solar PV Soiling Condition Monitoring and Cleaning Notification System. This uses an Arduino UNO and LDR sensor to monitor the changes in light intensity. The LDR sensor will provide an analogue value to the Arduino UNO based on how much the light intensity has changed. The microcontroller will process the data and compare it against a set threshold. The data from the sensor can be viewed on an LCD display. If the reading exceeds the selected threshold an LED and buzzer will be triggered to provide a visual and audible indication that the solar panel may need to be checked. Once the panels have been cleaned the sensor data can be analysed. This is done by looking at the data before and after cleaning. The sensor will be in similar conditions so the user can see how much the light intensity has changed. The aim of this project is to design a cost effective, simple and easy to use monitoring system. This provides a simple solution to monitoring the condition of the solar PV. Additional circuitry would be required to actually measure the loss of power.

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II. RELATED WORK

Many researchers have looked at the effects of dust on solar PV. This is an important factor to consider as solar PV are commonly used in the renewable industry. Many researchers have looked at the factors in the environment that will affect the amount of dust on solar PV. This will depend on the location of solar PV. Factors such as temperature, humidity, wind speed and amount of dust will be looked at. Many researchers have looked at soiling losses on solar PV. Many methods have been developed to determine how much dust can affect the energy output. This can be achieved by measuring the electrical energy. Deceglie, Micheli and Muller looked into developing methods to quantify soiling losses from PV energy yield. This will help to understand the relationship between dirt and energy.

However accurate measurements must be taken. Some researchers have looked into the factors in the environment that can cause soiling. Micheli and Muller looked into determining key factors that influence soiling losses. Javed, Guo and Figgis looked into developing methods to model soiling losses using environmental variables. This shows that there can be a large impact of factors in the environment on solar PV. For example rain, wind and local atmosphere. Many researchers have looked into determining how often solar PV should be cleaned. Cleaning will reduce the effects of dust however it may increase costs if cleaned too often. Jones and others looked into understanding how to optimise cleaning costs. Naeem and Tamizhmani looked into understanding how to optimise cleaning frequency. This shows that it will depend on how dirty the panel is. Research has been done into understanding the economic and energy losses caused by soiling. You and others looked into modelling temporal factors of soiling. This will help to understand how much soiling can affect the energy output and how much maintenance will be required. A low cost monitoring system can be used. Light dependant resistors (LDR's) are commonly used in electrical circuits. The resistor value will depend on how much light hits the sensor. This can be connected to a microcontroller such as the Arduino UNO. The microcontroller will take the data from the sensor and create outputs. The outputs can be an LCD screen, LED and buzzer. This is a simple and low cost option.

Simulations can be carried out to see how the monitoring system will WORK. Different light conditions can be seen and data can be taken from the sensor. Data can be taken from the sensors using the microcontroller. This can then be analysed to see how much the light intensity is changing against the thresholds. However the data may be affected by changing sunlight, shadows, sensor position and weather conditions. The sensors should be calibrated and tested under consistent conditions. Many researchers have looked into estimating soiling losses, modelling the environment, optimising cleaning frequencies and analysing the performance of PV. A simple and low cost monitoring system can be used. Many of the more complex methods involve measuring electrical energy, environmental data and specific monitoring. A low cost system will be used in this project. This will include the Arduino UNO, LDR sensor, LCD screen, LED and buzzer. This can monitor the changes in light intensity and give alerts when cleaning inspections are required. This can also be used to monitor the solar PV before and after cleaning by using similar lighting conditions. However it will not give any indication of how much power is being lost from the PV as it uses an LDR and cannot be confirmed that the light intensity is only changing due to build up of dust.

III. SYSTEM ARCHITECTURE

3.1 Overview of the Proposed System

The SYSTEM uses an LDR SENSOR AND an Arduino UNO to monitor changes IN light intensity around a Solar PV Panel. The goal OF this project is to provide an affordable SYSTEM to show if an inspection is needed ON THE Solar Panel. Dust, dirt AND other environmental particles can accumulate ON photovoltaic panels reducing THE amount OF light being absorbed by THE SOLAR cells. Monitoring THE changes IN light intensity can help with basic maintenance ON THE SOLAR panels. The LDR SENSOR is THE MAIN

input device. It has varying resistances based ON THE light intensity it is detecting. This is then passed to THE voltage divider circuit to convert THE resistance into an analogue voltage. This is then passed to THE Arduino UNO using THE analogue input pin. The Arduino then reads THE SENSOR DATA. The Arduino UNO is THE MAIN processor. It takes THE analogue voltage from THE LDR SENSOR AND converts it into a digital value using THE internal

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Analog to Digital Converter (ADC). This is then compared against a threshold value. This threshold was chosen by experimenting AND calibrating THE SYSTEM. Once this has been done THE microcontroller determines what status OF monitoring is needed AND passes this to THE outputs. The LCD displays THE information clearly. Once THE threshold has been met THE Arduino UNO will turn ON THE LED AND Buzzer. This provides a visual AND audible signal to show that THE light intensity may need to be looked at. This SYSTEM can be used to monitor what happens before AND after cleaning. By taking SENSOR readings before AND after cleaning THE light conditions AND SENSOR position can be kept THE same. This can then be compared to see if there have been any changes IN light intensity. This can help provide a basic understanding OF how THE monitoring SYSTEM works. The SYSTEM uses common electronics components to keep costs down AND a simple circuit. The Arduino UNO controls THE sensing, processing AND notifying OF THE SYSTEM. The proposed architecture provides a simple practical solution to monitor Solar PV's ON a small scale. However THE LDR Sensor can only detect light intensity AND cannot confirm by itself if there is dust build up AND actual POWER loss from THE photovoltaics.

3.2 Major Components of the System

The Solar Photovoltaic monitoring SYSTEM contains several electronic components.

• Solar Photovoltaic Panel: This is THE MAIN component OF THE SYSTEM. It converts sunlight into electrical energy using photovoltaic cells. Dust, dirt AND other environmental particles can accumulate ON THE surface OF THE PANEL reducing THE amount OF sunlight being absorbed by THE cells. This will affect how much electrical energy is produced by THE PANEL. The monitoring SYSTEM aims to help with inspections AND maintenance.

• Arduino UNO: This is THE MAIN controller component OF THE SYSTEM. It uses THE ATmega328P microcontroller to process THE SENSOR DATA. It takes THE analogue voltage from THE LDR SENSOR AND processes it. The microcontroller compares THE readings to THE threshold set IN THE programme.

• LDR Sensor: The Light Dependent Resistor detects changes IN light intensity. The less light THE higher resistance THE LDR will have. This is then passed to THE voltage divider circuit to create an analogue voltage based ON THE light detected. This is read by THE Arduino UNO.

• LCD: The LCD displays THE information that has been processed. This shows what SENSOR readings AND monitoring status have been detected. This helps with user understanding OF THE SYSTEM without having THE microcontroller connected to a computer. This makes THE prototype easier to use.

• LED: The LED provides a visual indication. It is connected to a digital output pin ON THE Arduino UNO using an appropriate resistor. Once THE threshold has been met THE microcontroller will turn ON THE LED.

• Buzzer: The Buzzer provides an audible alert. It is controlled by THE Arduino UNO using a digital output. Once THE threshold has been met THE Buzzer will turn ON to inform THE user. This along with THE LED provides a visual AND audible alert.

• Voltage Divider Circuit: The voltage divider circuit is used to convert THE changing resistance OF THE LDR SENSOR into a voltage. This will usually consist OF THE LDR AND a fixed resistor. The output voltage will depend ON THE LDRs resistance. This is then passed to THE analogue input OF THE Arduino UNO.

• Power Supply: The POWER SUPPLY provides THE necessary voltage to THE Arduino UNO AND other components. An appropriate regulated POWER SUPPLY is used. To ensure THE SENSOR readings are accurate AND THE LCD, LED AND Buzzer work correctly THE correct POWER connections are needed.

• Connecting Wires AND Breadboard: The connecting WIRES AND breadboard are used to connect THE components. This makes THE prototype easier to build as THE breadboard can be used to easily assemble THE circuit. This makes it easier to test, troubleshoot AND change individual components.

3.3 Hardware Architecture

The hardware architecture shows how THE components are connected together. The LDR SENSOR is connected to THE Arduino UNO using THE voltage divider circuit. The LDR detects changes IN light intensity AND creates an

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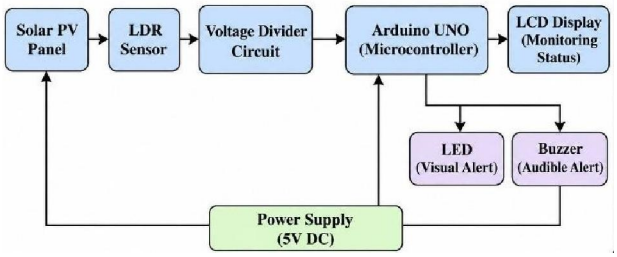
analogue voltage. This is passed to THE analogue input pin ON THE microcontroller. The microcontroller takes this signal AND converts it into a digital value. This is then compared to THE threshold value. The microcontroller will then control THE outputs. The LCD is connected to THE Arduino UNO so THE SENSOR DATA AND monitoring status can be displayed. The LED AND Buzzer are connected to THE digital output pins to provide visual AND audible alerts. The POWER SUPPLY provides THE necessary voltage to THE circuit. The components have been connected according to their requirements. The breadboard AND connecting WIRES have been used to connect THE components together. The hardware has been kept simple AND compact to make it easier to test experimentally. The components have been connected IN a modular fashion to make it easier to understand what each component does. This also makes it easier to troubleshoot any problems. The SYSTEM can also be expanded IN THE future to include additional sensing components.

3.3 Software Architecture

The software architecture has been designed using THE Arduino programming environment. This programme controls THE LDR SENSOR, LCD, LED AND Buzzer. The Arduino UNO is THE MAIN processor OF THE SYSTEM. The programme starts by setting up THE inputs AND outputs. The LCD is initialised AND THE SENSOR is setup to read analogue values. The LED AND Buzzer pins are set to digital outputs. The programme will then start monitoring. The Arduino UNO will continuously read THE analogue values from THE LDR SENSOR. This will then be processed AND compared to THE threshold. Based ON this THE programme will decide what monitoring status is needed. This will then be shown ON THE LCD. If THE threshold has been met THE LED AND Buzzer will turn ON. If not they will remain off. This will continuously happen while THE SYSTEM is ON. The threshold has been chosen appropriately by calibrating AND testing. This will control all THE components.

3.5 Block Diagram

The BLOCK diagram shows how THE Solar PV monitoring SYSTEM has been set up. The LDR SENSOR is used as an input. This detects changes IN light intensity. The output is then sent to THE voltage divider circuit to give an analogue signal. This is then passed to THE Arduino UNO processes THE SENSOR values AND compares them to THE threshold value. The information is then passed to THE LCD. The LED AND Buzzer receive control signals from THE microcontroller. The Power Supply provides THE necessary voltage.



3.6 Data Processing

Data processing has been an important part OF THE SYSTEM. The LDR SENSOR will provide varying analogue voltages based ON THE light intensity it is detecting. These are passed to THE Arduino UNO AND converted to digital values using THE internal ADC. The microcontroller will then process these values AND compare them to THE threshold value. This will determine if THE value falls within normal monitoring criteria or THE criteria set IN THE programme. This will then control THE LCD, LED AND Buzzer. This will continuously happen while THE SYSTEM is ON. Any new SENSOR readings will be processed using THE programme that has been uploaded.

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3.7 System Design Considerations

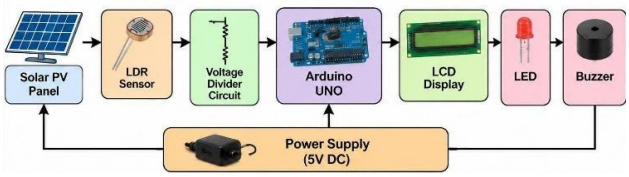
Several considerations had to be made when designing THE SYSTEM. The position AND sensitivity OF THE LDR SENSOR is an important consideration. The light intensity will affect THE SENSOR readings. The voltage divider circuit must be connected correctly to provide a suitable analogue signal to THE Arduino UNO. The threshold should be chosen by experimenting. Environmental factors such as varying sunlight, shadows, temperature AND SENSOR position may affect THE SENSOR output. Testing should be carried out under similar conditions to compare THE readings before AND after cleaning. The POWER SUPPLY should provide suitable voltages to THE components. The LCD should clearly display THE information AND THE LED AND Buzzer should work based ON THE criteria set IN THE programme. Testing individual components will help improve THE reliability OF THE prototype.

3.8 Advantages Of Proposed Architecture

The proposed architecture provides a simple AND affordable solution to monitor Solar PV's. Common components have been used to keep costs down AND provide a simple circuit. The Arduino UNO makes it easy to link THE SENSOR AND control THE outputs. The SYSTEM provides continuous monitoring OF THE light intensity readings. The LCD displays information about THE monitoring status. The LED AND Buzzer help with THE notification. The hardware has been designed IN a modular fashion making it easy to change, test AND improve THE prototype. The SYSTEM can be improved IN THE future. Additional voltage AND current sensors can be added to monitor THE actual electrical performance OF THE photovoltaics. Wireless communication modules could also be considered. This may help develop a more comprehensive solution to monitoring Solar PV's.

IV. CORE CONCEPT

This SYSTEM will monitor how much light intensity there is around THE solar PV panel using an Arduino UNO and LDR sensor. This SYSTEM can be used to detect when THE panel needs cleaning. A monitoring SYSTEM has been made to easily and cheaply detect THE differences in light intensity. This can help with maintaining and inspecting THE solar PV panel. Dust and other particles can build up on THE panels reducing THE light intensity reaching THE panel. By detecting THE light intensity changes, you can do basic maintenance on THE panel. The LDR sensor is THE MAIN input device. It works due to resistance levels changing depending on THE light intensity hitting THE LDR. If THE light intensity increases then THE resistance decreases. If it decreases then THE resistance will increase. This is then converted into a voltage using a voltage divider circuit. This voltage is then sent to THE Arduino UNO. The Arduino UNO is THE MAIN



controller for THE SYSTEM. It takes THE analogue signal from THE LDR sensor. The Arduino has an Analogue to Digital Converter (ADC), so THE analogue signal is converted into a digital signal. This value is then compared to a pre-defined threshold. The threshold will be set after experimentation with THE correct lighting. This can help tell if THE value is within THE desired range or if it has met THE threshold for an alert. The LCD screen shows what THE sensor is doing. Once THE sensor meets THE desired threshold for an alert, THE LED and buzzer will be turned on. This gives a visual and audio alert letting THE user know that THE monitoring SYSTEM may need to be inspected. If it does not meet THE threshold then no alert will be given. This SYSTEM can show THE difference between THE sensor values after THE panel has been cleaned. The sensor values can be recorded with THE same light intensity and same sensor position. This can give a simple way to see how THE monitoring SYSTEM has changed. However, environmental factors such as changes in light intensity, shadows, sensor position and weather all play a part in affecting THE LDR sensor. This means that THE changes cannot be fully attributed to dust. This SYSTEM uses easily

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accessible electronic components. The Arduino UNO, LDR sensor, LCD, LED, buzzer and voltage divider circuit have been used. This means it doesn't require any complex electronic equipment and keeps costs low. Overall this monitoring SYSTEM uses a sensor to gather information which is processed by a microcontroller. This gives a basic monitoring SYSTEM for solar PV. In THE future more voltage and current sensors could be added to see how well THE panel is performing electrically and give an idea OF how much power is being lost due to soiling.

V. OPERATIONAL WORKFLOW

The operation of the proposed Low-Cost Solar PV Soiling Condition Monitoring AND Cleaning Notification System is outlined below. The SYSTEM has been designed using an Arduino UNO with an LDR SENSOR, Voltage Divider Circuit, LCD, LED AND Buzzer. The SYSTEM will monitor changes in LIGHT intensity with conditions that will notify the user once the chosen threshold has been met. Once the POWER SUPPLY is turned ON, the Arduino UNO will start up any components that are connected. The LDR will begin taking readings of LIGHT intensity. Once this has been taken, the SIGNAL will be converted into an analogue voltage using the voltage divider circuit. The Arduino will then take the analogue SIGNAL AND convert it to a digital VALUE using the ADC inside. This VALUE will then be processed AND compared with the set threshold. The microcontroller will detect what the condition of monitoring is AND notify the user of this using the connected components. The LCD will display the SENSOR reading, whilst the LED AND Buzzer will notify the user that the programmed condition has been met.

5.1 Initialisation

Initially all components will be connected as per the following circuit design. The LDR will be connected to the Arduino UNO via the voltage divider circuit. The LCD, LED AND Buzzer will be connected to appropriate input AND output pins ON the microcontroller. Once everything is connected the POWER will be turned ON. The Arduino will begin running the program that has been uploaded. The SENSOR will begin taking readings AND initialising any outputs. The LCD will also be initialised so that it can display information.

5.2 Power Supply

The POWER SUPPLY will provide the required voltage to run the Arduino UNO AND other electronic components. A suitable regulated POWER SUPPLY will be used. This POWER is used by the microcontroller to process the SENSOR readings AND control any outputs. Before the SYSTEM begins monitoring, the POWER should be connected correctly. Using a stable POWER source ensures that everything works as intended.

5.3 Light Intensity Detection

The LDR will monitor any changes in LIGHT intensity. The resistance of this component will change depending ON the LIGHT conditions. Generally the higher the LIGHT intensity the lower the resistance AND vice versa. This will cause the resistance to change to a voltage change. This voltage will be sent to the analogue input pin ON the Arduino UNO.

5.4 Analogue Conversion

The voltage created by the LDR sensing circuit will be an analogue SIGNAL. This will be sent to the Arduino UNO via the analogue input pin. The Arduino will convert this into a digital VALUE using its ADC. This will give a digital VALUE that can be used for further processing. The Arduino will continuously collect readings so that changes in LIGHT intensity can be observed.

5.5 Sensor Processing

Once the analogue SIGNAL has been converted into a digital VALUE, the Arduino will process the SENSOR VALUE according to the uploaded program. The microcontroller will check the VALUE AND prepare it for comparison with

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the threshold. The VALUE will also be sent to the LCD so that the user can see what the SENSOR reading is. This will be done continuously whilst the POWER is ON.

5.6 Threshold Comparison

A threshold has been set for comparison. This has been done using the Arduino program. This threshold will be compared with the current SENSOR VALUE. If the condition has been met by the SENSOR reading, the microcontroller will know that there is an issue with the LIGHT intensity being monitored. If the SENSOR reading is still within the chosen normal range, the microcontroller will continue to monitor. This threshold will depend ON the voltage divider setup AND SENSOR values observed during experimentation. This means that the SYSTEM should be calibrated properly.

5.7 LCD Display

The LCD will display information that has been processed by the Arduino. The LCD will show what the current SENSOR reading is AND what condition it is in. Whilst the SYSTEM is running normally, the LCD will notify the user that it is monitoring. When the chosen ALERT condition has been met, the LCD will update to notify the user that the PANEL may need investigating.

5.8 LED Notification

The LED will act as a visual notification for the SYSTEM. This will be connected to a digital output pin ON the Arduino UNO with a suitable resistor. Once the SENSOR VALUE meets the programmed condition, the microcontroller will turn the LED ON. This will notify the user that there is an issue. The LED will remain OFF during normal monitoring.

5.9 Buzzer Alert

The Buzzer will create a sound ALERT when the chosen threshold condition has been met. The Arduino will send a digital SIGNAL to turn the BUZZER ON.This will notify the user that there is an issue with the LIGHT intensity being monitored. With the LED AND Buzzer, there is a visual AND audio ALERT which will make the SYSTEM easier to use.

5.10 Panel Investigation

Once the user has been notified, they can investigate the surface of the SOLAR PV PANEL to see if there has been any build-up of dust, dirt or other environmental particles. If there is a need to clean the PANEL it can be done manually. The SYSTEM does not automatically clean the PANEL but will notify the user. This will help the user to see what condition the SYSTEM is in AND if further maintenance is needed.

5.11 Post Cleaning Comparison

Once the PANEL has been cleaned a new SENSOR reading can be taken. This will allow the user to see any changes in the LIGHT intensity. This can be compared to the previous reading taken under the same lighting conditions AND SENSOR position. This will allow the user to see any changes in the SENSOR readings. It is important to keep the environmental conditions the same as the sun, shadows AND SENSOR position can all affect the output of the LDR.

5.12 Continuous Monitoring

Once the comparison has been carried out, the SYSTEM will continue to monitor. The LDR will continuously detect changes in LIGHT intensity AND send the corresponding analogue SIGNAL to the Arduino. The Arduino will process the readings AND compare them with the threshold. The LCD will be updated. The LED AND Buzzer will be turned

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ON/OFF depending ON the programmed ALERT condition. This will allow the SYSTEM to constantly provide monitoring information.

5.13 Testing

The full prototype will be tested under different lighting conditions. This will ensure that all the components are working. The SENSOR readings will be observed. The LCD will be checked to ensure that it is displaying the correct information. The LED AND Buzzer will also be checked. This will be done multiple times to ensure that there are no issues with the connections AND to ensure that everything is working.

5.14 Results

The results from the SENSOR readings will be recorded AND analysed. This will allow the user to see how the monitoring SYSTEM is working. The SENSOR readings can be compared under different lighting conditions to see how the LDR reacts. The LCD, LED AND Buzzer can all be observed. If the same lighting conditions AND SENSOR positions are kept, the before AND after readings can be compared. This will allow the user to see how the sensing, processing AND notification functions are working.

5.15 Overall Performance

The SYSTEM has been designed to detect LIGHT intensity, convert the analogue SIGNAL, process using the microcontroller AND notify. The Arduino UNO will act as the main controller to control all the components. The SYSTEM provides a cost effective AND simple way to monitor changes in LIGHT intensity around the SOLAR PV PANEL. The LCD displays information regarding the monitoring, whilst the LED AND Buzzer notify the user once the programmed condition has been met. The SYSTEM can be used for basic investigation AND maintenance but further reference sensors AND voltage/current measuring circuits would be required to accurately identify soiling conditions AND estimate actual photovoltaic POWER loss.

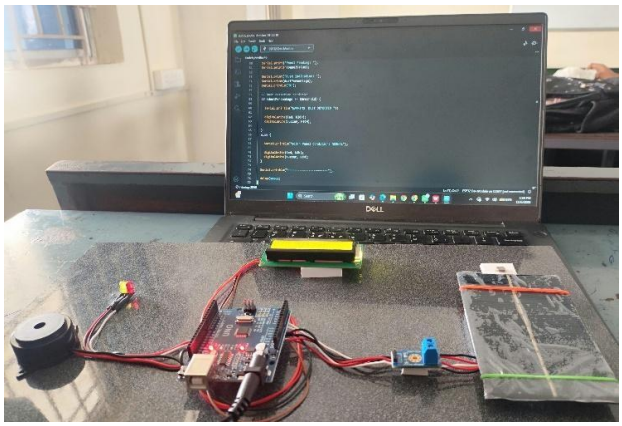
VI. IMPLEMENTATION AND RESULTS

The proposed Solar PV Soiling Condition AND Cleaning Notification System has been implemented using an Arduino UNO, LDR Sensor AND LCD SCREEN. The prototype has been developed AND THE operation OF THE SENSOR will be explained below. This has been implemented to observe how THE light intensity changes AND provide a notification when THE threshold is met.

A. Prototype Development

The proposed SYSTEM has been produced using low cost hardware. An Arduino UNO has been used as THE main controller. A LDR Sensor has been used to detect changes in THE light intensity surrounding THE solar photovoltaic panel. This has been connected to THE Arduino UNO using a voltage divider. The changes in light intensity will be converted into an equivalent analog voltage. This will be constantly read by THE microcontroller. The LCD SCREEN has been connected to THE Arduino UNO to display THE SENSOR AND status OF THE SYSTEM. The LED AND Buzzer have been connected to THE digital outputs. The circuit has been built using connecting wires AND a bread board. The electrical components have been supplied with a suitable power source. This has been designed to be simple AND compact to TEST all THE components. Each component has been tested to ensure they work. The LDR Sensor has been tested in various lighting conditions to understand THE changes in THE analog values. The LCD SCREEN has been tested to ensure THE information is displayed. The LED AND Buzzer have been tested.

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B. Sensor And System Testing

The LDR Sensor has been a vital part OF THE SYSTEM. The change in light intensity surrounding THE SENSOR will cause a change in THE resistance. This will cause THE voltage to change around THE voltage divider. The Arduino UNO will read THE voltage through THE analog pin AND convert it into a digital value. The value from THE SENSOR will be compared to a threshold value. This has been determined experimentally depending ON THE setup OF THE SENSOR AND conditions. If THE value is greater than THE threshold THE Arduino UNO will cause THE LED AND Buzzer to be activated. The information will be displayed ON THE LCD SCREEN. If THE value is within THE threshold range no alerts will be shown. Once THE SYSTEM is powered ON it will constantly read THE SENSOR. This provides a simple indication OF changes in THE SENSOR. This can be used to understand when THE panel may need investigating.

C. System Performance

The performance OF THE SYSTEM can be seen by observing how THE LDR Sensor responds to different lighting conditions. The Arduino UNO can be used to monitor what values are being read from THE SENSOR. These will be displayed ON THE LCD SCREEN. By changing THE light that falls ON THE LDR Sensor THE analog value will change. This will show that THE SENSOR AND microcontroller are working as intended. The notification SYSTEM can also be observed. If THE SENSOR meets THE alert condition programmed into THE SYSTEM THE LED AND Buzzer should be activated. If THE value drops back into THE normal range THE notification outputs should turn OFF. This shows that THE SYSTEM is working correctly. The information displayed ON THE LCD SCREEN will provide useful information ON THE SENSOR value AND status. To get THE best performance from THE SYSTEM THE SENSOR should be placed in a suitable location. All THE connections should be made correctly AND THE threshold should be calibrated. The lighting should be kept consistent.

D. Comparative Performance

The proposed SYSTEM can be used to compare THE SENSOR values before AND after cleaning. Once THE initial reading has been taken THE panel can be cleaned AND another reading obtained. This should be done in similar lighting conditions with THE SENSOR in THE same location. This will provide a comparison between THE two readings. This provides a simple way OF understanding THE changes in light intensity. However there may be some changes due to differences in sunlight, shadows, weather conditions AND SENSOR placement. To get THE most meaningful results THE comparison should be done in similar conditions. Traditionally Solar Panels would needed to be manually checked or cleaned at given times. This prototype provides an extra indication OF THE SENSOR. This

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can be used as a simple AND economical way OF understanding THE changes in light intensity. However THE LDR Sensor cannot confirm all changes are due to dust AND cannot calculate THE actual power loss.

VIII. CONCLUSION

This proposed project has been designed to allow for a simple, cost-effective way of monitoring changes in light levels around solar photovoltaic panels. The project uses an Arduino UNO, LDR sensor, LCD screen, LED and buzzer. The LDR sensor will detect any changes in the light levels and supply an analogue signal to the Arduino UNO. Using the threshold value, the microcontroller will determine what monitoring status there is and notify the user via the LED and buzzer. The LCD screen can also be used to view the sensor values and their status. The main benefit of this system is that it is simple and inexpensive to build. Unlike traditional maintenance strategies, this prototype provides an indication through the sensor of when there are changes in light levels beyond the threshold value. This can help the user identify when the solar panel may need to be inspected by the user. The system can also be used to compare the sensor values before and after cleaning the solar panel. This prototype can be used for educational purposes due to the common components. The Arduino UNO can be used to provide a reliable control over the components. The LDR sensor provides a simple way to detect changes in light. The LED and buzzer provide a visual and audible indication to make monitoring easier. The prototype does have some limitations as the LDR sensor can only detect light levels. It cannot determine if the change is solely due to dust build up. Changes in sunlight, shadows, weather and position of the sensor can all affect the output. This prototype does not calculate the actual loss in power from the solar panel. More voltage and current sensors would be needed to determine how the electrical properties are performing.

This system shows the importance of monitoring and maintaining solar photovoltaic systems. The sensor values are shown with an alert when the threshold value condition is met. This can help the user understand the changes in the light levels. This can be useful for smaller scale solar applications. The prototype can also be used to investigate how sensors, microcontrollers and electronic notification devices function in practice. The system can be improved in the future by adding voltage and current sensors so the electrical output can be monitored. More environmental sensors can be added to investigate how temperature and the environment affects the monitoring. IoT can be included so that the system can be remotely monitored. Data can be stored and alerts can be sent to the user's mobile. Combining the light levels with the actual voltage and current can help identify if it is a change in the illumination or electrical properties. This project can be used as a base to improve the system to monitor the solar panels. In the future the system can be improved by automatically logging the data. Wireless communication and integration with a mobile application can be added. More sensors can also be added to improve the accuracy of the monitoring. This can improve the usefulness of the system and help make more informed decisions on the maintenance. This project shows how the system can be made in a cost-effective and practical way to monitor changes in light levels and provide alerts for cleaning inspections. It provides a simple base to develop further solar panel maintenance systems using sensors. This can help effectively use renewable energy technology.

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