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Photovoltaic Plants Monitoring and Cleaning System

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Abstract: ***Photovoltaic plants and off-grid connections have been a solution for rural and remote areas in the past few years. It is, however, requiring a group of technicians to maintain the efficiency of the PV panels in a regular based. PV panels also suffer a steady reduction in their effectiveness due to the need for cleaning and environmental aspects.***

The project monitors the output of individual PV connected in the array and advises timely maintenance. The technology of wireless sensor networks consists of a small device. Efficiency trends are to be utilised to activate the cleaning robot to travels the given path and cleans the suspected PV and then moves to the next one as required.

Index Terms: Photovoltaic plants; Cleaning System; Zigbee;

I. INTRODUCTION

PV panels often work at a low efficiency when installed in a remote area. The efficiency reduction is mainly due to the need for regular cleaning as the panels are directly exposed by air pollution. [1] and [2]. The main challenge on the efficiency control is the fact that PV panels often work in collaboration. And hence it would be difficult to evaluate the efficiency of each panel. Monitoring the PV system has been implemented by mean of the wireless and wired network in several projects. Here a flexible wireless network has been utilised to share the information and make the required correcting decisions.
If an array determined to have a low output compared to the production collected from other PV panels, a correcting action could be taken in place. A portable robot is dedicated to performing the cleaning actions and then return to the usual schedule as required.

II. MONITORING SYSTEM

Monitoring production of PV panels facilitates the diagnosis of panel's operation in a solar farm or an array.

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Several phenomena may cause a reduction in energy generation of photovoltaic systems, including dust accumulation and dirt and physical damages.
The total maximum producible energy in a solar panel system is a function of the overall healthy operation of individual solar panels. Malfunctioning process of a single panel reduces the functionality of the solar array depending on the number of panels installed in the array. Negligence of the lowering of generation causes a more significant energy reduction due to more panels would be expected to have reduced functionality due to the environmental difficulties and aging. Therefore, monitoring each PV panel may contribute to maintaining the power produced from that PV panel and minimise problems on the PV panel array by monitoring the operation of each PV panel.

Several works implemented monitoring systems for Photovoltaic panels. FSK network has been utilised in [3] to monitor individual panels at a remote location. Wifi communication has been employed in [4] and [5] to determine the efficiency using remote terminal units. Wired network with the internet connection for panels is implemented in [7] and [7].
The monitoring system being used here is based on the Zigbee protocol to take advantage of the network flexibility and the energy consumption of the technology.

A. Overview of the monitoring and signalling system

In order to monitor the quantified functionality of PV panels, a monitoring module is employed to measure the energy production and signal irregularities from each panel. Figure 1 illustrated the employment of the monitoring module for two PV panels.

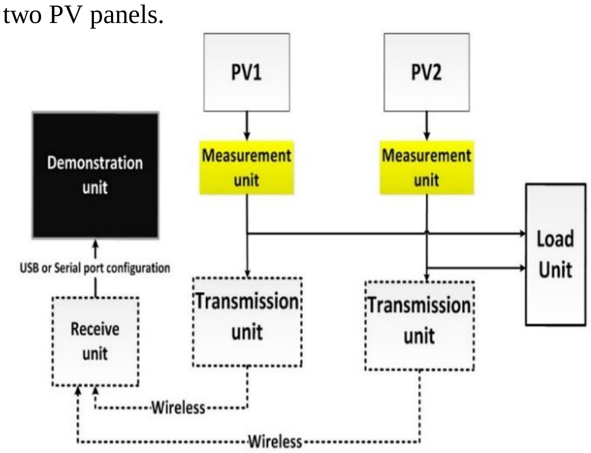

Fig. 1 Schematic of the monitoring system

PV panels are arranged in an array and either connected in series to increase the generated voltage or in parallel to increase the generated current. Figure 2 demonstrates the series and parallel connections of PV panels in the array.

In parallel string-connected layout, the current of each PV panel is the same as the series additive, and the voltage remains the same. If each PV panel in Figure 2 has an output of 18 volts and is 1A and the maximum output of the solar panel would be 4A, and the voltage would remain at 18V.

The monitoring module should be appropriately placed to distinguish the current and voltage of panels from those coming from the connected panels.

Current and voltage sensors determine the generated energy by signalling the production of their reading. A Zigbee transmission unit has been employed to transmit the generated power to the monitoring server in a predetermined schedule. And finally, the monitoring server collects data from the transmission units. There is also an LCD screen provided to display the output reading of each PV panel at the monitoring site. The information stored in a database to generate energy trends. A GUI program process and demonstrates the information received from the solar farm as requested.

Figure 2 has an output of 18 volts and 1 A., Then the total voltage of the PV panel array would be 72 V, and the current would remain at 1 A.

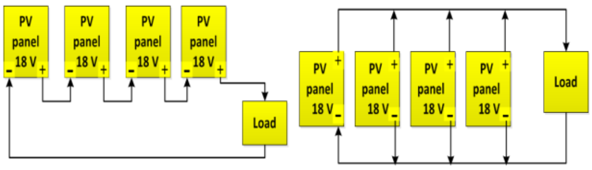

Fig. 2 Layout of PV panel in an array is series and parallel connection

Wireless sensor network for PV panels has been implemented previously via Bluetooth communication for a short range. Here Zigbee communication has been utilised to improve the flexibility and the range of communication.

Each PV panel is provided by an Xbee module. An XBee module has been utilised as the primary collector. It is interfaced with a computer via serial communication. A visual c++ graphical user interface has been used to retrieve and process the data acquired from the collector module.

Output. The prototype and communication pattern is shown in Figure 3.

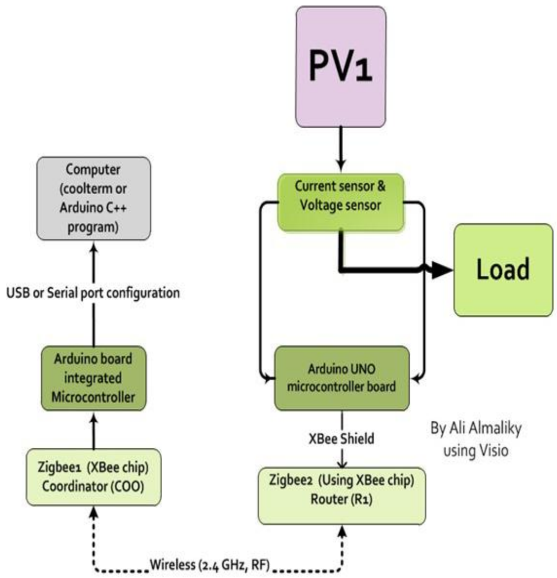

Fig. 3 Block diagram of the zigbee communication module

An Arduino UNO microcontroller has been utilised to pre-process the information using a current sensor. Details of the transmission and measurement system for PV measurement units is shown in Figure 3. The transmission unit is designed only to transmit the data when a change detected to reduce power consumption.

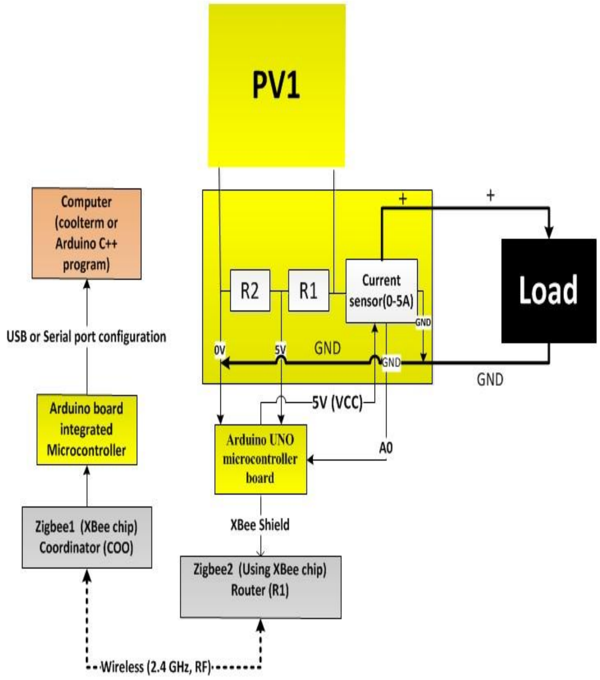

Fig 4 Schematic diagram of transmission and measurement unit for each single PV unit

In order to determine the power generation and facilitate the transmission, an Arduino Uno microcontroller has been employed. The microcontroller is connected to an Xbee transmission module to facilitate the communication when needed. The Zigbee coordinator's sensor relates to the computer to receive the data (The measured voltage and current) from the Zigbee router sensor. The data transmitted from XBee boards then will be accumulated in the data acquisition system and stored in an excel file which is interfaced with the monitoring and user interface system.

The current of the transmission each PV is processed initially using the Microcontroller to verify whether it is higher than the threshold set-point value or not. If the current generated remains below the expectation for an hour, a warning signal will be transmitted to the receiving unit using the Zigbee boards. The data then will be transmitted to the central unit to trigger the cleaning robot. The threshold set point varies to refract the change of daytime and consider the solar profile of the site. The plan reduces the data transmission between measurement units and the receiver to the necessary situation, and hence, affectedly minimizes the energy consumption of the monitoring system. Figure 4 is showing the current reading of a given PV, as described above

The central unit then may decide whether to trigger the cleaning request of affected panels. The triggering time is a function of several modified panels and a minimum interval between cleaning operations.

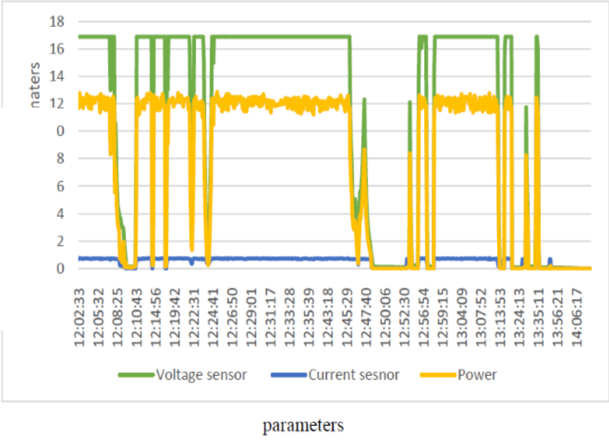

Fig 5 Output current, voltage and power of a given PV panels

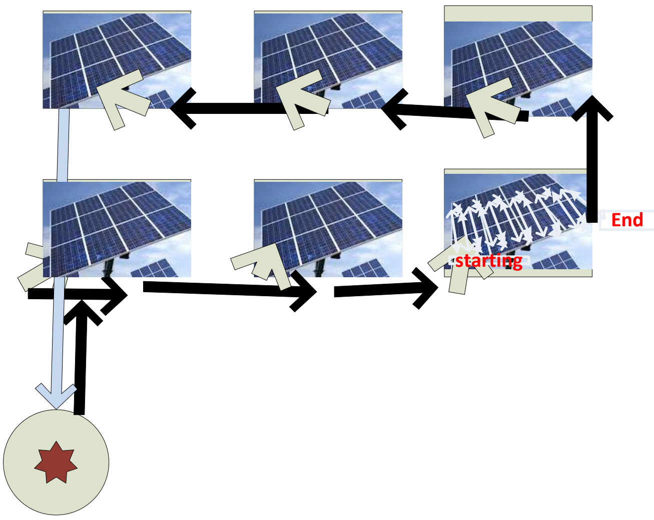

Fig. 6 The robot moves from one panel to another and clean the preselected panels as triggered by the monitoring system

Transmission units may consume a high amount of energy. Overall, the power consumption depended on the transmission time. Therefore, they are set to transmit the power in intervals of 20 minutes when they are generating above the half of the capacity of the panel and send in intervals of one 30 minutes when they produce less than half the nominal power — the transmission unit set to send no data during the night time.

III. ROBOTIC CLEANING SYSTEM

A commercialized cleaning robot has been used to perform mechanical cleaning tasks. The program then has been modified to facilitate cleaning the sloppy surface of solar panels.

The robot follows the given path until spotting the suspected PV array, then it starts the process of cleaning from the left corner and continues the scanning until the end — figure 5. When the panel's edge detected, the robot informs the completion of the process of cleaning and returns to the normal schedule. The cleaning algorithm of the Robot is shown in Figure 6. The PV cleaning system has used the original features of the cleaning robot for automatic charging and returning to the original location. The movement pattern of the robot has been manipulated to ensure the stability of the system while cleaning sloppy PV panels.

As shown in Figure 6, the moving pattern of robot changes as the touch sensors engage. Initially, the robot follows a given path until reaching the suspected PV panel. Then it is following a cleaning pattern to scan the surface of PV in a zig-zag form. When the edge detected, the robot changes direction and returns the same path with a shift, and when two edges detected, the robot follows the predefined path as the cleaning noted to be completed. The robot then finds its way to the next panel and continue the process until reaching the edge of the last panel in the array. There is a specific path designed for the robot to approach PV panels and return to the original location.

A physical link between PV panels is required to assure the continued operation of the cleaning robot. Otherwise, the robot is only approaching one panel and will go back to the central point after the cleaning operation has been completed for the panel. Locations of panels and the return path are given to a database to initiate the movement. The movement then will follow the random pattern, as explained before. The robot's operation is shown in figure 8.

IV. CONCLUSION

A novel cleaning scheme for PV panels has been demonstrated. The cleaning system operates whenever required and clean affected panels. A single robot should be able to cover a good number of arrays. This scenario is cheaper than alternative methods as permanent instating is not required. Also, the system contributes to the overall efficiency of the generation system as can address the affected panel immediately after generated current reduces below the threshold due to the accumulation of dirt, dust and bird's droppings.

The system, however, detected to consume a considerable amount of energy due to the transmission of signals and movement of mechanical parts. At present the system is only economically justifiable for big solar farms where reduction of the system's efficiency inures high costs. Further optimizations are necessary to maintain the energy consumption low and hence assure the high performance of the solar farm.

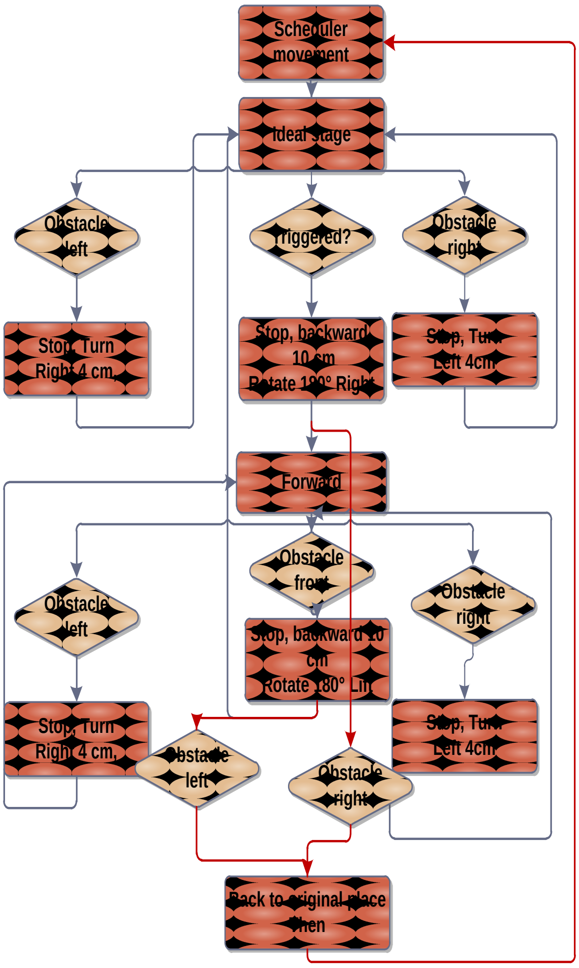

Figure 7 cleaning's robots process of searching and scanning

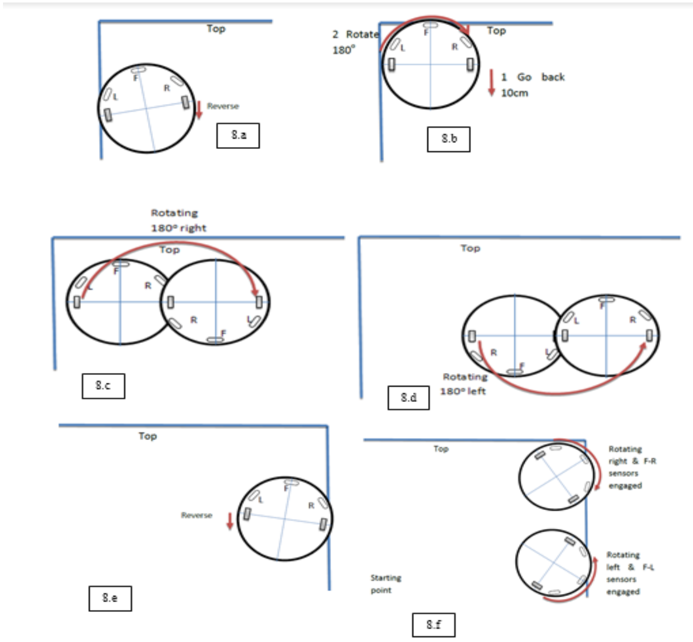

Fig. 8. Operation of the robot at different phases.

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