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Improving Monitoring and Fault Detection of Solar Panels Using Arduino Mega in WSN

Ali Al-Dahoud, Mohamed Fezari, Thamer A. Al-Rawashdeh, Ismail Jannoud

Abstract**—**Monitoring and detecting faults on a set of solar panels, using a wireless sensor network (WNS) is our contribution in this paper, this work is part of project we are working on at Al-Zaytoonah University. The research problem has been exposed by engineers and technicians or operators dealing with PV panel's maintenance, in order to monitor and detect faults within solar panels which affect considerably the energy produced by the solar panels. The proposed solution is based on installing WSN nodes with appropriate sensors for more often occurred faults on the 45 solar panels installed on the roof of IT faculty. A simulation has been done on nodes distribution and a study for the design of a node with appropriate sensors taking into account the priorities of the processing faults. Finally a graphic user interface is designed and adapted to tele-monitoring panels using WSN. The primary tests of hardware implementation gave interesting results, the sensors calibration and interference transmission problem have been solved. A friendly GUI using high level language Visual Basic was developed to carry out the monitoring process and to save data on Excel File.

Keywords—Component, Arduino Mega microcontroller, solar panels, fault-detection, simulation, node design**.**

I. Introduction

JORDAN is one of the counters which occupies high ranking in solar radiation which considered as 5.6 KWh/m2/day on yearly average, and southern region are the highest in Jordan which can reach to 6KWh/m2/day.

According to Fig. 1, we can conclude that the most appropriate alternative energy resource is the sun, for the reasons sustainable, eco-friendly, cost effective.

Also according to Jordanian Minister of Energy and Mineral Resources in 2010, the Kingdom of Jordan imports 96 percent of all its energy at a cost of US$3.6 billion or 13.5 percent of GDP. The Master Strategy of the Energy Sector in Jordan has set a target of 1,800 MW, or 10 per cent of the country's energy supply, to come from renewable sources by 2020. The Strategy calls for 600 MW of this new capacity to be provided by solar power.

Moreover, the south of Jordan receives a substantial amount of annual solar radiation per unit area, with an average annual total radiation exceeding 2500 kWh per year per square meter, as shown in Fig. 1 and illustrated in depth in Fig. 2.a

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Different technologies can be used to convert solar energy into electrical power, and these can be categorized into two main groups: thermal technologies and photovoltaic (PV) technologies, PV technology is considered a reliable alternative to fossil fuel which can be implemented in a wide range of settings as in [1]-[3] and in [5].

To monitor a set of solar panels in a large field we need more electronics and power electronics components which are subject to faults, the weather conditions also can cause faults.

Even if the probability of a fault or total failure of one component throughout the service life of a PV power plant is extremely low, the very large number of components in one PV power plant makes this probability likely to happen. Typical fault causes include weather damage from lightning strike, for example. Insects and rodents too can cause faults if they infiltrate the system and cause damage. Overloads in the supply grid can force output power reductions or even shutdowns. A reduction in yield is unavoidable in these cases. Every small fault within a PV power plant can reduce yield and quickly result in significant financial losses.

To obtain early warning of faults and creeping changes, monitoring and control of a PV power plant via a central unit is indispensable. Only in this way the operator can introduce repairs and maintenance measures at an early stage and thus, avoid costly downtimes.

A central role in monitoring and control of a PV power plant is played by the monitoring and recording of electrical and non-electrical variables of the PV modules, the inverters, and the medium-voltage components.

Monitoring of electrical variables is necessary for those cases in which the causes of faults and failures are sought [4].

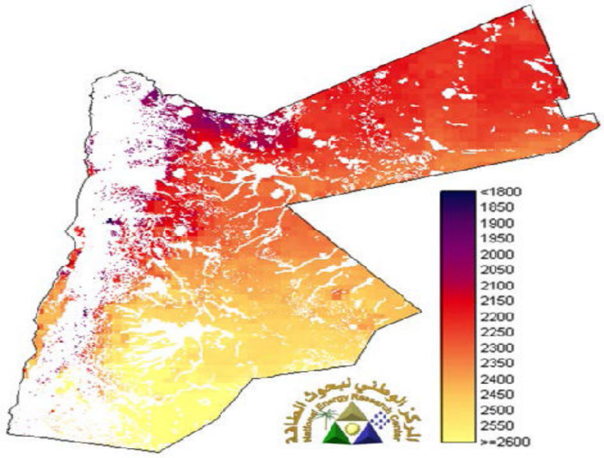

Fig. 1 Solar Energy distribution in Jordan Value in Kwh/m^2/day

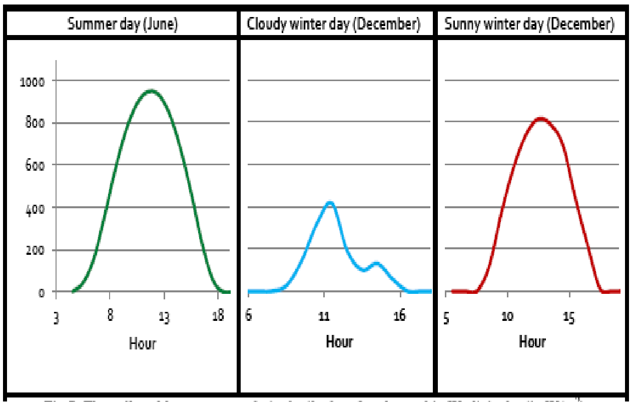

Fig 2. a: Collect table energy on a latitude tilted surface located in Wadi Araba (in W/m2)

Advanced control can help reduce operating costs and increase solar plant performance. The main control challenges are:

1) Optimal robust control techniques able to maintain the operating temperature as close to optimum as possible despite disturbances such as changes in solar irradiance level (caused by clouds), dust and other operating conditions.
2) Optimal and hybrid control algorithms that determine optimal operating points and modes and take into account the production commitments, expected solar radiation, state of energy storage, and electricity tariffs.
3) Algorithms to estimate main process variables and parameters from heterogeneous and distributed measurements (oil temperature and solar radiation at different parts of the field, mirror reflectivity, thermal losses).
4) Fault detection and isolation in solar power plants. Algorithms are needed to detect and isolate faults and malfunctions in power plants, such as detection of hot spots, receivers with broken glass covers or vacuum losses, and heliostat faults.

II. Proposed Design

AT Faculty of IT, we installed 45 solar panels (from well-known company in solar energy solution in Amman) on the roof. A training period of 2 weeks AT Faculty of IT Al-Zaytoonah University Amman, has allowed us to get more data on installed Solar Panels, as in [5] during the training some problem are raised and discussed with technicians and operators. Description of photovoltaic system:

The system is composed as in figure 2.b of PV Array of three lines with 13 panels for the first and second line and 18 for the third line the output of the 3 lines are applied to an inverter DC/AC of 12.8 Kw. The characteristics of two main elements in the system are:

1) Solar panel type PS-P60, presented in catalogue in [6], the module composed of 60 cells multi-crystalline with maximum power of 250Wp production per module. These modules are suitable to be used for most electrical power applications and have excellent durability to prevailing weather conditions. Its characteristics are as follow: open circuit voltage produced 37 volts, rated current at maximum power is 8 Amper and maximum power is 250wp. Dimension of panel (mm) 1655 x 990 x 40.
2) Inverter: in order to integrate the produced energy from solar panel directly to national grid, a DV to AC three phase inverter of type PVI-12.5 TL-OUTD [6] is used; it is designed for commercial usage, this three-phase inverter is highly unique in its ability to control the performance of PV panels, especially during periods of variable weather conditions. This transformer less device has two independents MPPTs (Maximum Power Point Tracker) and efficiency rating of up to 97%. The wide input DC voltage makes the inverter suitable for low power installations with reduced string size. It is available with an optional fully-integrated DC switch fuse and remote controller DC disconnect function. The unit is free of electrolytic capacitors, leading to a longer product lifetime.
3)

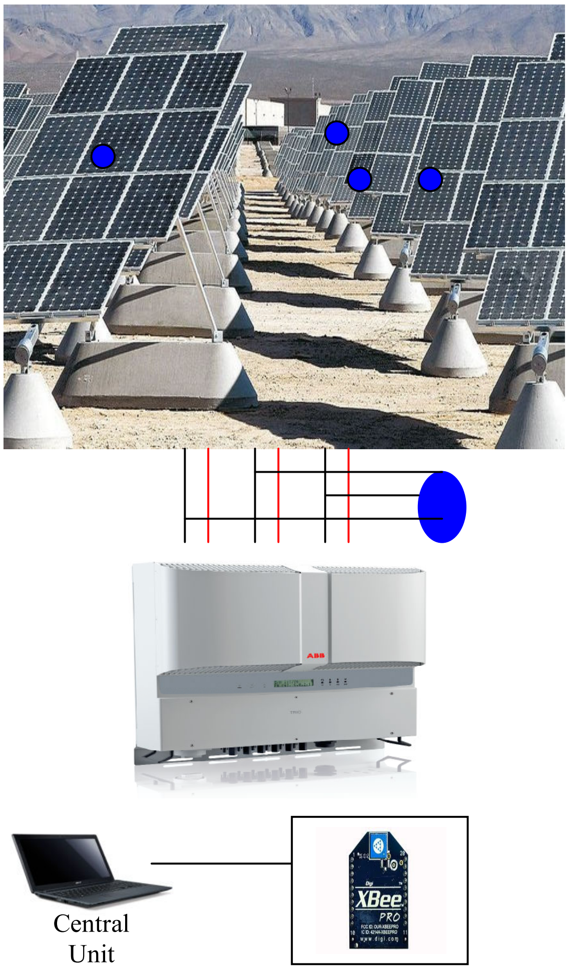

Fig. 2 .b: A proposed system with inverter and nodes (in blue) and Xbee modules as transmitters

Due to these power electronics and small electronics components, because of the environment of the PV Array the system is affected by degradation in power production. During the training period, the operators presented different faults and anomalies associated to the PV cells and power electronics components. During it is functioning, an installed PV panel is subject to different faults and anomaly these faults are different from PV array to another. Based on our research we have collected some irrelevant faults on PV panels plant as in Fig. 2.b and its electronics, these faults have been classified based on their statistics of occurrence.

Six default groups have been notified:

Default in the PV panel, Default in PV array switch, default in cables, default in Ground fault protection, and default in transformer DC/Ac default in data acquisition system.

Some fault in PV panel were mentioned by technicians such as full destruction and dispiriting of PV, the main fault that concern more the operators and technicians in CDER are presented here by priority: PV stolen or destroyed, pollution as dust, heat of cells, humidity penetration within the cells and light degradation.

A. Fault Detection Solution

Due to faults frequently presents on the PV array and the difficulty for the technicians and operators to travel to the field for maintenance, we proposed a wireless sensor network (WSN) solution. The proposed solution is to install on each PV panel a WSN node, each node control and monitor a PV panel and transmit the data to a gateway node as in figure 3, the information is then forwarded to the central unit via internet where the operator can monitor at distance the set of PV arrays vi a graphic user interface as human machine communication program.

A detailed study for node design is necessary, based on the choice of the microcontroller of DSP circuit to implement and the set of necessary sensors to add. A reflection of the type of radio frequency module for data transmission and communication protocol is indeed necessary.

B. Wireless Sensor Networks

A WSN is a system comprised of radio frequency (RF) transceivers, sensors, microcontrollers and power sources [10]. Recent advances in wireless sensor networking technology have led to the development of low cost, low power, multifunctional sensor nodes. Sensor nodes enable environment sensing together with data processing. Instrumented with a variety of sensors, such as temperature, humidity and volatile compound detection, allow monitoring of different environments. They are able to network with other sensor systems and exchange data with external users [19].

Sensor networks are used for a variety of applications, including wireless data acquisition as in [9], machine monitoring and maintenance, smart buildings and highways, environmental monitoring, site security, automated on-site tracking of expensive materials, safety management, and in many other areas as in [7].

A general WSN protocol consists of the application layer, transport layer, network layer, data link layer, physical layer, power management plane, mobility management plane and the task management plane as in [7] and [10].

Currently two there standard technologies are available for WSN: ZigBee and Bluetooth . more details in [11]-[15]. Both operate within the Industrial Scientific and Medical (ISM) band of 2.4 GHz, which provides license free operations, huge spectrum allocation and worldwide compatibility. In general, as frequency increases, bandwidth increases allowing for higher data rates but power requirements are also higher and transmission distance is considerably shorter [24],

[25]. Multi-hop communication over the ISM band might well be possible in WSN since it consumes less power than traditional single hop communication [25].

It is also possible to create a WSN using Wi-Fi (IEEE 802.11), but this protocol is usually utilized in PC-based systems because it was developed to extend or substitute for a wired LAN [24]. Its power consumption is rather high, and the short autonomy of a battery power supply still remains an important disadvantage [25]. WSN have large domain of applications [7],[8] and[14].

C. WSN Communication Architecture

The nodes are generally disposed in a zone to sense, each of these nodes has the possibility to collect data and route it to one or more nodes or base station. The base station collects all the data then transmit it via a communication link eventually internet, the user can also use the base station to send some command to this network of nodes. In [16] there is an interesting example.

The choice of sensors depends not only on type of default we would like to detect but also on interfacing it with microcontroller, the design should simplify the modification of the role of a node by simple adding or modifying or suppressing a sensor. A better solution for that would be to use digital sensors with I2C communication port.

The choice of powerful microcontroller with I2C communication port large program memory including some characteristics such as: timers, ADC converter, EEprom for data conservation, watch dog timer, sleep mode and some parallel ports.

The protocol of communication is composed of a packet 8 bytes designing: destination address, emitter address (ID of panel), type of fault and date and time.

The power circuit for the microcontroller and sensors modules is provided directly by the PV panel; however it is better to add a battery for secure situation.

D. Node Design

Effective construction of a WSN needs the development of nodes adapted to the specific characteristics of the application as to be as small as possible, reduced price, efficacy in power consumption, equipped with calculator and memory and with adequate communication resources.

As in Fig. 3, for the design of adapted node for this application, we opted for Arduino Mega as microcontroller because of its characteristics [17]. To communicate with digital sensors, protocol I2C is used, this protocol uses just two lines for communication (SCK to transmit clock signal, SDA to transmit data and address) . The Xbee module type “OEM Xbee” were selected as radio frequency transmitter of the node , it swell suited for the design of WSN since it is in standard ZigBee/IEEE 802.15.4., the module can reach a distance of 100 meters with baud rate 250 Kbps an it has a sensitivity of -92dbm.

III. Type Sensors for the Pv Panel Fault Detection

Based on priority for faults detection, we selected some sensors with I2C communication link:

A. SFH5712:

As light sensor, high precision I2C interface and low power consumption and low sensitivity to temperature coefficient. The SFH 5712 detects ambient brightness in the same way as the human eye, and offers not only the I²C standard data rates but also high speed rates of up to 3.4 MHz:.

Without the need for any additional control commands, an integrated circuit in the sensor automatically provides a measured value twice a second. The sensor has only four connections and takes up very little space. It can easily communicate through its integrated I²C interface. No analog circuit elements are needed. With 150 µA during operation and only 1.5 µA in stand-by mode, the sensor consumes extremely little power.

B. LM75:

As temperature sensor: The LM75 is a temperature sensor, Delta-Sigma analog to digital converter, and digital over-temperature detector with I2C interface. The host can query the LM75 at any time to read temperature. The open-drain over temperature Shutdown (O.S.) output becomes active when the temperature exceeds a programmable limit. This pin can operate in either ``Comparator'' or ``Interrupt'' mode. The LM75's 3.0V to 5.5V supply voltage range, low supply current, and I2C interface make it ideal for a wide range of applications. These include thermal management and protection applications in personal computers, electronic test equipment, and office electronics.

C. SHT21:

As humidity sensor: The extremely small SHT21 digital humidity and temperature sensor integrates sensors, calibration memory and digital interface on 3 x 3 mm footprint. Additionally the humidity sensor provides electronic read-out of tracking information. The complete over-molding of the sensor chip - with the exception of the humidity sensor area - protects the fully calibrated and reflow humidity and temperature sensor against external impact and leads to an excellent stability against aging, shock and volatile chemicals. Output: I²C digital, PWM, SDM/analog Volt, interface, RH operating range: and RH response time: 8 sec (level 63%).

D. LM3812:

As current sensor: The LM3812/LM3813 Current Gauges provide easy to use precision current measurement with virtually zero insertion loss (typically 0.004Ω). The LM3812 is used for high-side sensing and the LM3813 is used for low-side sensing. A Delta Sigma analog to digital converter is incorporated to precisely measure the current and to provide a current averaging function. Current is averaged over 50 ms time periods in order to provide immunity to current spikes. The ICs have a pulse-width modulated (PWM) output which indicates the current magnitude and direction.

E. GP2Y1010AU0F :

Is a dust sensor by optical sensing system. An infrared emitting diode (IRED) and a phototransistor are diagonally arranged into this device. It detects the reflected light of dust in air.

Especially, it is effective to detect very fine particle like the cigarette smoke. In addition it can distinguish smoke from house dust by pulse pattern of output voltage. Direct current 20 mA, output I2C.

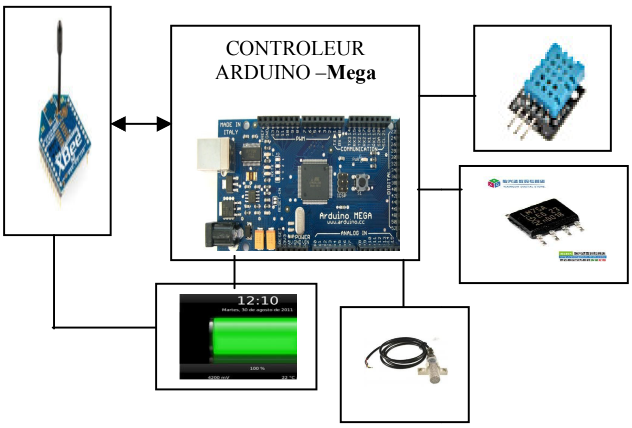

Fig. 3. Proposed solution of the Node, Node with modular structure for adding or suppressing digital sensors

F. Operating Program installed Within the PIC

The software MPLAB has been used as environment development tool under windows, the tools is provided by Microchip, on reset the system reads current sensor and test the value of the current if it is not normal then detect if the panel is destroyed or specific fault is detected.

IV. WSN SIMULATION

We have done a comparative study between 5 usual simulators (NS2, OPNET, WSNsim, Moteview and QualNet) and a research on paper dealing with comparative study , see in [19], [20], [21] and [22] while using as reference a real testbed based on recent Imote2 sensors. The simulators give different results even in similar environments. NS2, WSNsim and Qualnet give results close to those of the experimentation in the case of an indoor environment, but in the outdoor environment Opnet and Moteview give results closer to the reality however Moteview is dedicated to popular nodes MICAZ and MICA2 from Crossbow and it has an easy to use graphic interface. The choice of Moteview as simulator for the WSN application is imminent.

The Moteview tool as in [23] by Crossboy, provides in real-time the information concerning the environment following a certain topology of network. We can get different data from sensors installed on nodes and transferred to gateway witch transmit the data to the central unite via a serial port, we get the information concerning this panel (source current, temperature, humidity, light, position and status of battery), each node has an address referred as an ID number and presented during transmission, with Moteview, the user can select any node by its ID number to visualize the data collected in that node. We call this operation “refreshment”, in this operation the central unit sends an interruption to desired node, then the concerned node weak up gets data from sensors, arrange the packet and transmit the collected data as packet with checksum byte to the central unit directly or via gateway, the central unit process the data and present result on GUI as in Fig. 5.1.

A. Results of Simulation Using Visualization tool Moteview

MoteView [23] monitoring software is a Crossbow’s product to visualize WSNs which provides users to simplify deployment and monitoring. It also makes it easy to connect to a database, to analyze, and to graph sensor readings. The Mote-view features topology and network statistics visualization as well as logging of sensor readings and the viewing of the logged data. The statistics function includes the end-to-end data packet yield, a prediction for the future and the RF link quality, but is limited to these features. It allows querying the sensor network for collected data in a database-like manner, hiding the distribution of the data collection software on the sensor nodes, Some MoteView simulation results are presented in Fig. 4.a which shows the evolution of sun light during the day and night and cumulated current during this period. Fig. 4.b.

We have made some test by simulation some faults on a panel and we registered the evaluation of temperature and current within a panel. The results are shown in Fig. 5.a and 5.b

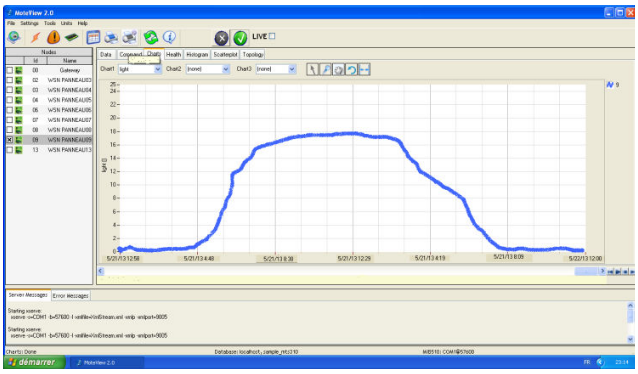

Fig. 4.a: evolution of light on panel n:9 during 24 hours

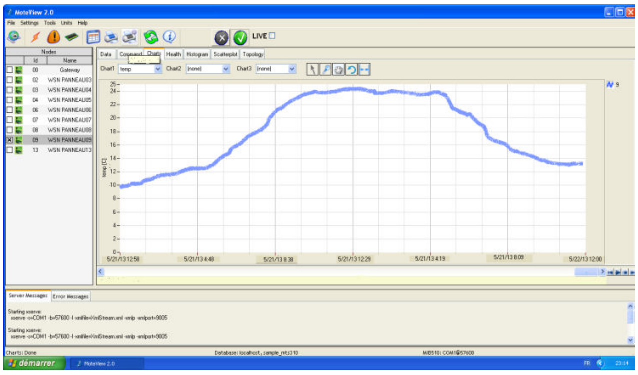

Fig. 4.b Evolution of temperature on the panel during 24 hours

B. Development of simulator based on WINCC

SIMATIC WinCC is a supervisory control and data acquisition (SCADA) and human-machine interface (HMI) system from Siemens. It can be used in combination with Siemens PCS 7 and Teleperm control systems. WinCC is written for the Microsoft Windows operating system [18]. The software Wincc has been used to develop HMI.

The proposed simulator is composed of two windows for global visualization of the PV fields' status and specific visualization for the status on each PV panel. As presented in figure 4, the upper part is used as inputs parameters to simulate faults (five faults can be simulated from low to high errors using the sliders in upper right side of the figure 4) and to select the panel number (1 to 12 using buttons in upper left side of figure 4), the lower part represent the set of panels forming the field and the color of each panel represent the degree of fault (green: normal, orange: partial fault implies partial reduction of acquired energy and red : total destruction of the panel or big fault detection such as short circuit).

Some tests were done and results are shown in Fig. 5.a and 5.b

Fig 5.a illustrates an error due to high temperature on panel number 8. This high temperature causes destruction of the panel. However the simulation of no current available in a panel number 5 is presented in Fig. 5.b, this is due either to destruction of panel or electronic components deterioration.

Fig 5.a: Case of dangerous Fault in Panel number 8 due to Temperature

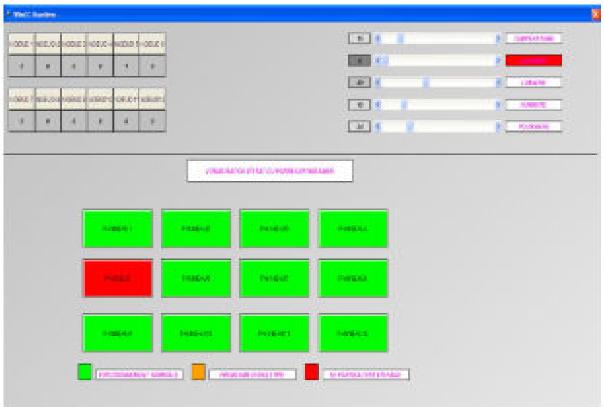

Fig 5.b. Case of dangerous Fault in Panel number 5 due to current

V. Conclusion

In this work we studied the feasibility of WSN to monitor a set of Solar PV Panel installed on the roof of Faculty of It at Al-Zaytoonah Unversity Amman in Jordan. The simulation by an adequate simulator gave encouraging results, the development of specific interface to simulate faults was done and test gave good results, then the study of the conception of the nodes has been scanned and architecture of the sensors node is presented. Adapted sensors for the application, based on engineers need, are selected. The modular topology of the hardware design allows the user to insert and remove easily digital sensors from principal module.

Continuous monitoring and control of large PV power plants is the requirement for consistently high yields and thus for economic success. Only early detection of faults and creeping wear and tear make it possible to provide rapid remedies, minimize reductions in yield, and avoid yield failures. For monitoring and remote operator control of PV power plants, we studied specially prepared hardware and software components. These components form a sound tool for displaying the status and probable faults in the PV power plant with type of fault, and enabling operator control from a remote control center.

Our perspective work, includes improvement of the GUI as HM Interface, also real installation of the proposed solution will provide some difficulties on real environment than that of simulator, trade of on designing our proper nodes or use some of the shelf like that of MICAz of Crosbow, communication protocol should be tested and improved regarding the situation of the environments.

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