Forest Fire Detection Using Optimized Solar – Powered Zigbee Wireless Sensor Networks

U. Arun Ganesh, M. Anand, S. Arun, M. Dinesh, P. Gunaseelan and R. Karthik

Abstract— Forest Fires are one of the most important and prevalent type of disasters and they can create a great deal of Environmental Impacts due to which their early detection is very vital. The main need for choosing this particular application for the detection of forest fires is to overcome the demerits present in the existing technologies of MODIS and Basic Wireless Sensor Network-based Forest Fire Detection Systems and an advanced system is developed for the detection of forest fires. The two main modules present in the project are the Monitoring Area Module and the Forest Area Module. All these together are split into five sub-modules for step-by-step development and implementation. Those include Sensors' Module, Serial Communication Module using Zigbee, Optimized Solar Energy Harvester using Maximum Power Point Tracking (MPPT), PC-based Web Server and Mechanical Modeling. The first three sub-modules belong to the Forest Area Module. They are integrated together and mechanical modeling is done to place it in the forest, whereas, the PC-based Web Server is developed for the Monitoring Area. The outcome of the above implementations reveal that various sensors used in addition to the temperature sensor improves security level for areas located near the forests. It also shows that the Optimized Solar Energy Harvester increases the efficiency to about 85 % and the use of PC-based Web Server reduces the bulkiness and cost of the entire system.

Index Terms— Mechanical Modeling, MODIS, Optimized Solar Harvester, Serial Communication, Server, Wireless Sensor Network and Zigbee

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1 Introduction

Forests are part of the important and indispensable resources for human survival and social development that protect the balance of the earth ecology. However, because of some uncontrolled anthropogenic activities and abnormal natural conditions, Forest Fires occur frequently. These fires are among the most serious disasters to forest resources and the human environment. In recent years, the frequency of forest fires has increased considerably due to climate changes, human activities and other factors. The prevention and monitoring of Forest Fires has become a global concern in Forest Fire prevention organizations. Currently, Forest Fire prevention methods largely consist of Patrols, Observation from watch towers, Satellite Monitoring (Fu et al.) and lately Wireless Sensor Networks (Han et al.). Although observation from watch towers is easy and feasible, it has several defects. In the first place, this method requires many financial and material resources and a trained labor force. Second, many problems with fire protection personnel abound, such as carelessness, absence from the post, inability for real-time monitoring and the limited area coverage.

The scope of application of Satellite Detection Systems is also restricted by a number of factors, which reduces its effectiveness in Forest Fire Detection. Due to the demerits in Satellite-based Detection Systems, Wireless Sensor Network Technology was used to detect Forest Fires and send the information to the computers in the Monitoring Centers. The collected data will be analyzed and managed by the Computer. Compared with the normal meteorological information and basic forest resource data, the system can make a quick assessment of a potential fire danger. The analytical results will then be sent to the relevant department as the policy-making basis by which the department will make the decision of firefighting or fire prevention (Jiang et al., and Chan et al.).

2 Satellite-based Fire Detection Systems

One of the most popular Satellite-based Fire Detection System is based on MODIS (Hook et al.). The Moderate Resolution Imaging Spectroradiometer was sent to space by NASA for capturing the Earth surface to detect Forest Fires. The problems associated with this system is that it has a long scanning cycle (Fukuda et al.) i.e., it takes maximum of two entire days to capture the entire surface of the Earth before sending it to the Earth station for Forest Fire Detection analysis. The analysis takes so long according to equation (1).

$$\text{Time taken} = \text{Image Capturing time} + \text{Image Sending time} + \text{Processing and Analyzing time} + \text{Distribution time} \quad (1)$$

The resolution of its saturated pixel dots of images is low as per Fig. 1. The figure shows images revealing the characteristic of low resolution. Even if the processed image

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is zoomed to detect small areas of Forest Fire, it cannot be determined because of the low resolution of the image.

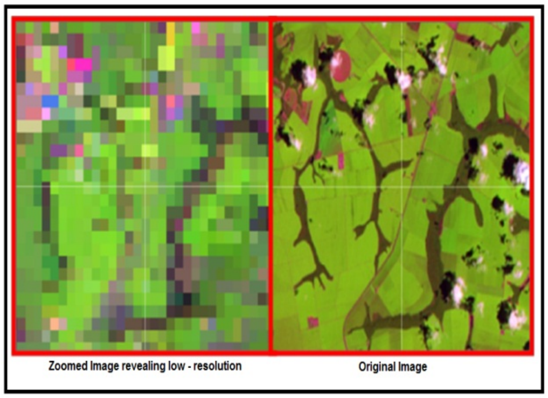

Fig. 1 Images revealing the Characteristic of Low-Resolution

Another problem is that the cloud layers may mask images during the scanning period and the real-time mathematical quantification of fire parameters is very difficult to achieve. An example of cloud layers masking is shown in Fig. 2. The figure shows a real-time image of Forest Fires blocked by clouds in various areas of the Forest from top view. As per the figure, when the clouds mask Forest Fires, it becomes impossible for Satellite-based Fire Detection Systems to capture the hidden fires from space. This demerit cannot be overcome in anyway in Satellite-based Forest Fire Detection Systems. So this proves to be a major demerit in such Systems.

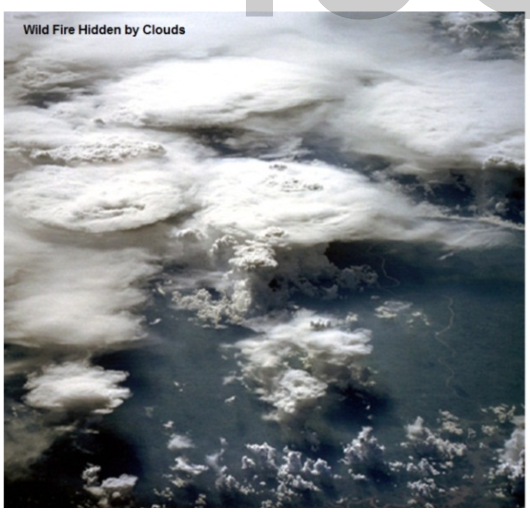

Fig. 2 Cloud Interference blocking Forest Fire Detection from Top View

3 Basic Wireless Sensor Network-based Fire Detection Systems

Wireless Sensor Network-based Forest Fire Detection Systems that were implemented initially after Satellite-based Fire Detection Systems comprised of basic Radio Frequency modules and a normal Solar Energy Harvesting System. The basic RF module that was used for Wireless Communication is based on CC2430 chip from Chipcon which has certain disadvantages. Other modules like EZ430-RF2500 from Texas Instruments were also used for Wireless Communication. When the distance between the two RF modules are increased, the power loss increases exponentially so it is not possible to move away two modules to cover a large area with low power loss. In addition, the current consumption of the module during receive operation is 19.4 mA and 23 mA during transmit operation which is quite high and inefficient.

Fig. 3 shows the Basic Wireless Sensor Network-based System for Forest Fire Detection. A Wireless Sensor Network, which combines computer and communication technology with the technology of a sensor network, is considered to be one of the ten emerging technologies that will affect the future of human civilization. This network is composed of numerous and ubiquitous micro sensor nodes which have the ability to communicate and calculate. These nodes can monitor sense and collect information of different environments and various monitoring objects cooperatively. A SimpliciTI module EZ430-RF2500 from Texas Instruments was used as a RF module for wireless communication.

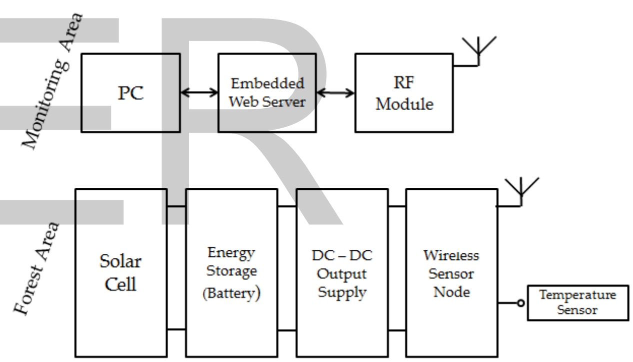

Fig. 3 Basic Wireless Sensor Network-based Forest Fire Detection System

3.1 Structure of the Sensor Node

The Sensor Node is a basic unit and platform of the Wireless Sensor Network. A sensor node is commonly composed of a sensor module, a processing module, a wireless communication module and a power module. Fig. 4 shows the structure of the sensor node.

The sensor module is responsible for data analog-digital conversion and collecting parameters such as relative humidity of the atmosphere and air temperature. The processing module is responsible for controlling the operation of the whole sensor node and saving and coping with data collected by its own node and the binary information transmitted from other nodes. The wireless communication module is responsible for communication with other nodes and exchanging control information and receiving or transmitting data. The power module supplies power for the other three modules and drives the nodes, making it the key factor for the effective operation of the network.

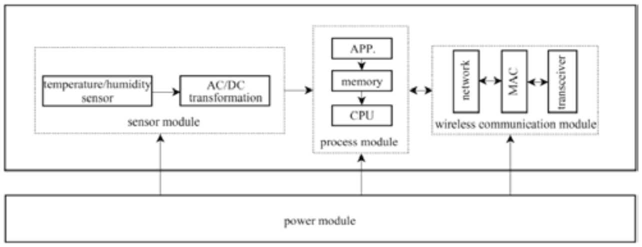

Fig. 4 Structure of a Sensor Node

3.2 SimpliciTI

The SimpliciTI module used is EZ430-RF2500 from Texas Instruments and is shown in Fig. 5. This module was chosen because of its simplicity, small dimensions and low price. It consists of the following devices:

- 2 boards with MSP430F2274 microcontroller and CC2500 transceiver with chip antenna, two LEDs and push button.
- USB interface for programming and communication with PC
- Battery holder with connector to transceiver board

This module is thought as a development tool for wireless sensor networks and can be used as a standalone device or incorporated into an existing project.

Fig. 5 EZ430-RF2500 – SimpliciTI Evaluation Module

3.3 Experimental Results of SimpliciTI Module

Results of transmission power loss due to distance increasing between transmitter and receiver are shown in Fig. 6.

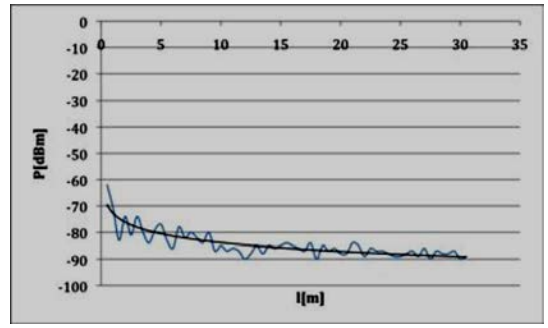

Fig. 6 SimpliciTI Transmission Power Loss due to Distance Increasing between Transmitter and Receiver

The maximum distance at which most data packets were transmitted is about 30 m which is lower than 50 m (Grimaldi et al.). Also the maximum transmission distance can be affected by the orientation of antennas of both transmitter and receiver.

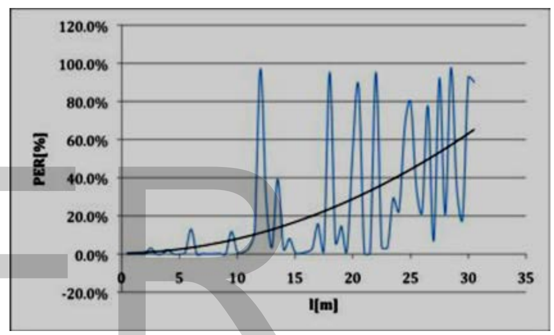

Fig. 7 SimpliciTI Packet Error Rate Increase due to Distance Increase between Transmitter and Receiver

Packet Error Rate was fluctuating up to about 24 m and rapidly raised at the distance over 24 m. The maximum distance where all packets were lost was about 30 m.

TABLE 1

SimpliciTI Current Consumption in Different States

Idle	19 mA
Receive	19.4 mA
Transmit	23 mA

The current consumption, shown in Table 1 reveal that even during idle state, the module uses a high current. This is a drawback as power is not saved efficiently.

4 ADVANCED PROPOSED SYSTEM FOR FOREST FIRE DETECTION

The block diagram of the Proposed System is shown in Fig. 8. The Proposed System overcomes all the drawbacks of the Satellite-based Forest Fire Detection Systems and Basic Wireless Sensor Network-based Forest Fire Detection Systems.

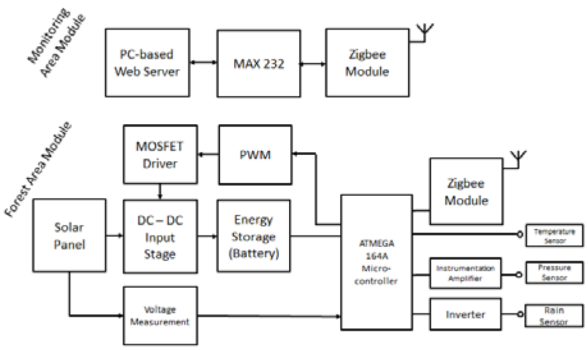

Fig. 8 Proposed System

4.1 SENSORS AND INTERFACING

Three Sensors namely, Temperature Sensor, Pressure Sensor and Rain Sensor are used to detect the occurrence of Forest Fire, Abnormal Prowling and Rain respectively. The Temperature Sensor used is Thermistor: **RL0703-624-73-MS** from ATC Semitec Limited. The main need for Thermistor is to detect Forest Fire. The advantage of using thermistor is that it helps in knowing the Temperature variations in several areas of the Forest, whereas the Fire Sensor will detect only Fire and will not give the Temperature variations of those areas. The main need for Pressure Sensor is to detect Abnormal Prowling in the Forest Areas which may be due to some trespassing or some wild animal. It is mainly used to detect trespassers near the borders of countries which are covered by Forests. The Pressure Sensor used is MPX2010D from Freescale Semiconductor. Rain sensor is used to detect rainfall in the Forest Area. The main need for Rain Sensing is when rain falls in some Forest Areas, the residents or the areas near the Forest may be subjected to floods and landslides. In order to warn the people near the Forest Areas about the possibility of Flood occurrence and Landslides due to rain, this sensor is used. The Simulation results of interfacing Temperature Sensor and Pressure Sensor with the Microcontroller are shown in Fig. 9 and Fig. 10. Simulations are done in the beginning to check the integrity of the developed Embedded C Code which will be used finally for hardware implementation.

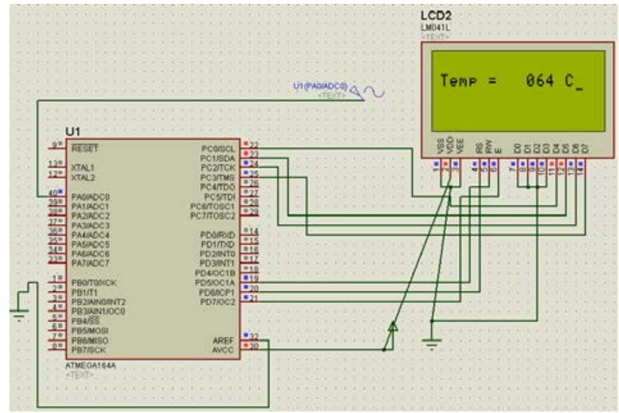

Fig. 9 Simulation Output for Temperature Sensor Interfacing

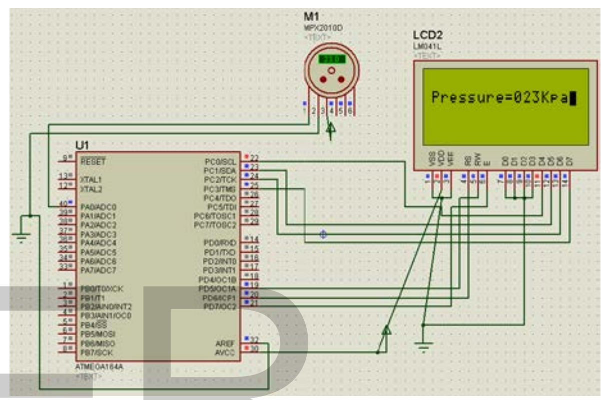

Fig. 10 Simulation Output for Pressure Sensor Interfacing

4.2 Design of Instrumentation Amplifier and Inverting Amplifier

The signal sensed by the Pressure Sensor produces an output at two terminals of the Pressure Sensor which cannot be interpreted by other circuits as it is of very low value. Output at two terminals means the output from the two ends of the Piezo electric crystal. In order to amplify those signals, Instrumentation Amplifier is used. To get Finite, Accurate and Stable gain, the Instrumentation Amplifier is designed accordingly. The design equations of Instrumentation Amplifier and the chosen Resistance values for the design are as follows. The resistances are chosen such that large varieties of resistances are not involved i.e., resistances with almost same or nearest values are chosen.

The output state of Instrumentation Amplifier is a basic differential amplifier. The output of the basic differential amplifier is given by the following equation.

$$V_o = R_2/R_1\ (V_{02} - V_{01})$$

(2)

The final output of the Instrumentation Amplifier is given by the following equation.

$$V_o = (R_2/R_1).(1+2R_f/R_G).(V_2-V_1)$$

(3)

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As per design, the values of resistances are chosen and we are increasing the gain of the signal by 204 times so that the Signal will easily be interpreted by the external circuits.

The designed circuit of the Instrumentation Amplifier followed by the Inverting Amplifier with respect to the design equations is shown in Fig. 11.

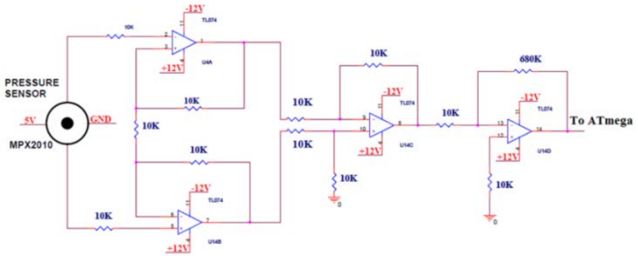

Fig. 11 Instrumentation Amplifier and Inverting Amplifier

4.3 Hardware Results of Sensors

Fig. 12 shows the graph of Output Voltage of the Thermistor in mV against Temperature in degree Celsius. A soldering iron was used to increase the temperature of the Thermistor and it returned increased values of voltages as the temperature was increased. The output voltage is proportional to the temperature and the graph shows the normal working of the Thermistor. Similarly, Fig. 13 shows the graph of Pressure vs. output voltage from inverting amplifier. It is evident from the graph that when pressure is increased, the piezoelectric crystal produces more voltage due to increased mechanical stress. The instrumentation amplifier and the inverting amplifier give an amplified version of the Pressure Sensor Output. The graph shows the normal working of the Pressure Sensor as the Pressure is proportional to the output voltage generated by the Pressure Sensor.

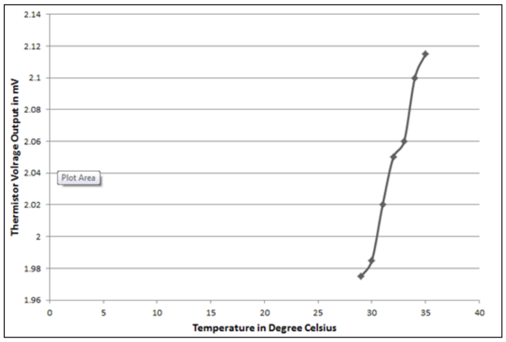

Fig. 12 Temperature vs. Thermistor Output Voltage Graph

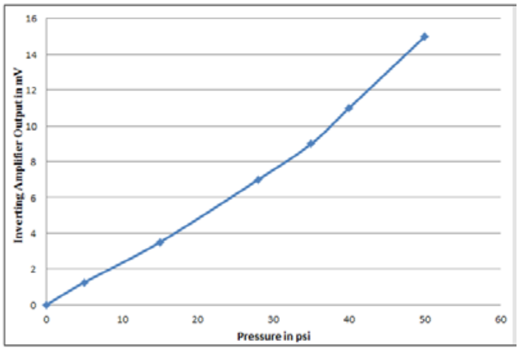

Fig. 13 Pressure vs. Inverting Amplifier Output Voltage Graph

4.4 Development of Rain Sensor

Fabricated aluminum lines separated by very short distance are used as a rain sensor. The rain sensor is designed with a PCB Design Software called ExpressPCB after which the Sensor is fabricated. Fig. 14 shows the PCB model of the Rain Sensor developed using ExpressPCB and its hardware equivalent after etching.

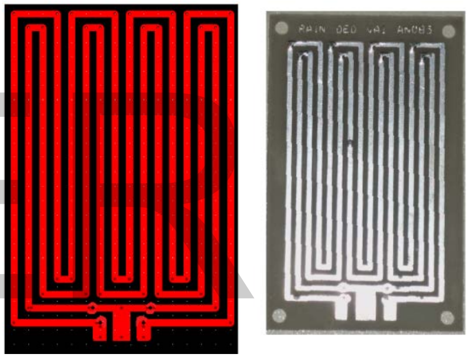

Fig. 14 ExpressPCB Rain Sensor Development and Fabricated Rain Sensor

5 OPTIMIZED SOLAR ENERGY HARVESTING

Normal solar harvesters do not utilise power generated during dim sunlight and so the efficiency of the solar harvester becomes very less. Even during bright sunlight, the light to the solar panel maybe blocked by leaves or other matter. Due to this, the entire focus of sunlight to the solar panel is lost. We propose a methodology for optimizing the solar harvester with maximum power point tracking for the wireless sensor network nodes. The development of perpetually powered systems avoiding periodical battery replacement and/or recharge is one of the ultimate goals in sensor network design. Maximum Power Point Tracking (MPPT) techniques are very common in the world of large-scale solar cells. The extra energy that is consumed by the Maximum Power Point (MPP) tracker is easily offset by the much higher amount of energy that can be harvested from the environment.

Sensor nodes are often required to be small, and therefore, they are powered by small solar cells that generate limited energy. For those cells, the gain in input energy is not always higher than the additional losses that are caused by the MPP tracking operation. The energy consumption and efficiency of the MPP tracker are, therefore, very important design criteria in energy harvesting for sensor nodes. The optimization of the energy harvesting process under varying light irradiance conditions is certainly one of the major design challenges. In particular, maximizing harvester circuit efficiency becomes fundamental at low light irradiance. There are different algorithms for MPPT and at present more advanced algorithms are developed for increased efficiency of the solar harvesters. Perturb and Observe algorithm and Incremental Conductance algorithm are subjected to high relative efficiency. These two algorithms are compared again to find the suitable one for our implementation. Incremental Conductance algorithm is complex to implement and requires more time for processing. Perturb and Observe algorithm is simple to implement and takes less processing time. Also Perturb and Observe algorithm is used for many systems. So Perturb and Observe algorithm is chosen for the current solar harvester (Faranda et al.).

5.1 Working and Simulink Model

The working of Perturb and Observe Algorithm is explained with the help of a flowchart. The flowchart is shown in Fig. 15.

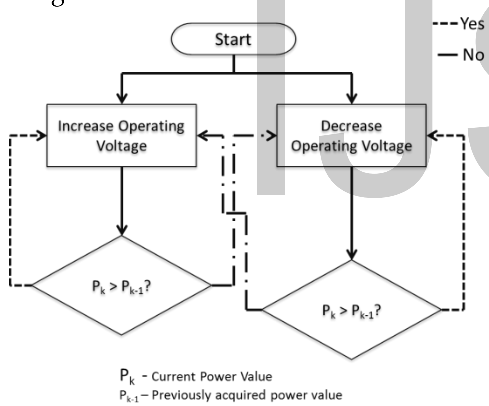

Fig. 15 Flowchart for Working of Perturb and Observe Algorithm

According to the Perturb and Observe Algorithm, when the system is switched ON and if irradiation is present, the operating voltage increases. P_k is the current power value calculated according to the current operating voltage. P_{k-1} is the previously acquired power value. The algorithm compares P_k and P_{k-1} and when $P_k > P_{k-1}$, the operating voltage is decreased and vice-versa. The process is again repeated after decreasing the operating voltage. This continues infinitely. So the two main steps involved in the Perturb and Observe Algorithm is comparison and updation of the power values. A Simulink model is initially developed before implementing it to hardware in order to check the correctness of the algorithm. The Simulink model of the algorithm is given in Fig. 16.

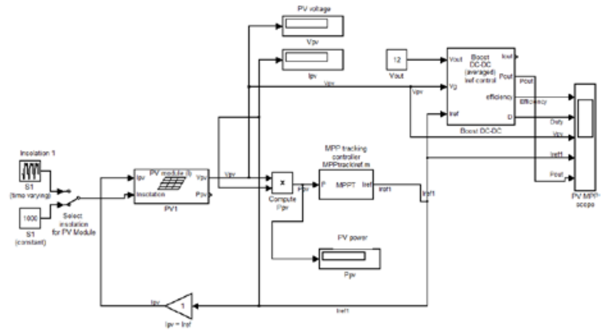

Fig. 16 Simulink Model for Perturb and Observe Algorithm

The Simulink model consists of two types of insolation. They are constant insolation and time varying insolation. Only one type of insolation can be selected with the help of a selection switch. Here two types of insolation are given to compare the results under different conditions. The value of 1000 in the constant insolation box represents the maximum radiation from the sun. Depending upon the insolation, the Photovoltaic (PV) module generates voltage. Initially the reference current (I_{ref}) is provided by the MPP tracking controller. For initial working conditions, I_{ref} is given through a Matlab program associated with the MPP Tracker. There is also another Matlab program associated with MPP Tracker. It performs the actual comparison and updation of V_{pv} which is the photovoltaic voltage. The V_{pv} generated will be compared with the threshold and will be boosted up to V_{out}. Here V_{out} is the actual output required and it is chosen as 12 as 12 V is required to charge the Battery and for other normal operations of the system.

5.2 Simulation Results

The overall efficiency of the Perturb and Observe Algorithm and the output power maintained by the P & O Algorithm are shown in Fig. 17.

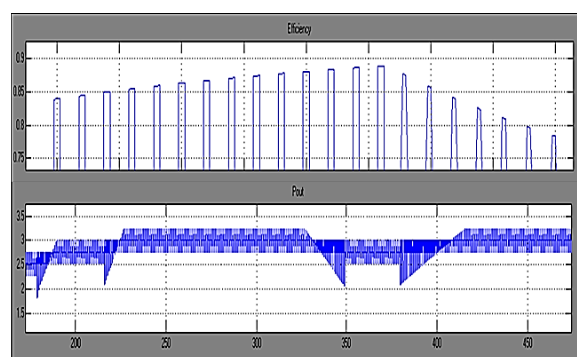

Fig. 17 Simulation Results showing Efficiency and P_{out} of P & O Algorithm

As per the graphs, the maximum efficiency is obtained to be around 90 %. So, on optimum, an efficiency of around 85 % will be obtained. The graph also shows that the P_{out} is maintained to a constant value of about 3 Watts. The output graph is not a constant line as it takes little time for the P & O Algorithm for its comparison and updation processes.

5.3 Hardware for Optimized Solar Harvester

The hardware blocks for implementation of MPPT are given in Fig. 18. It contains the blocks that are necessary to perform Maximum Power Point Tracking for the optimized solar energy harvesting system.

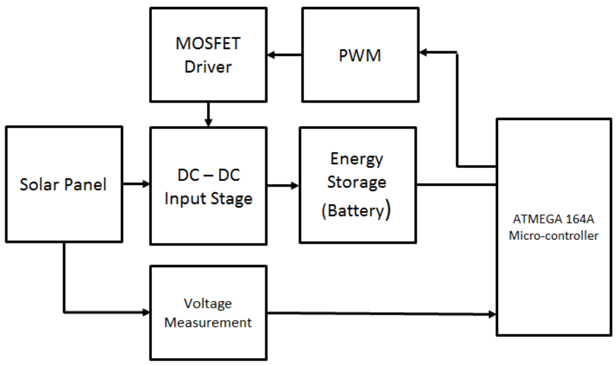

Fig. 18 Hardware Blocks for MPPT

A mono-crystalline solar panel is used as mono-crystalline panels have no internal losses unlike poly-crystalline solar cells. For the MOSFET Driver and DC-DC Input Stage blocks, a MOSFET and a Darlington pair is used for switching. Also an inductor is used for charging and discharging during conversion. A Rectifier is used for AC to DC conversion and finally potentiometers are used for controlling the Input and Output voltages. PWM and Voltage Measurement are done by the Microcontroller. The Perturb and Observe Algorithm is written in the Microcontroller by developing its equivalent Embedded C Code. The Darlington Circuit for switching is given in Fig. 19 and the DC-DC Boost Converter is shown in Fig. 20.

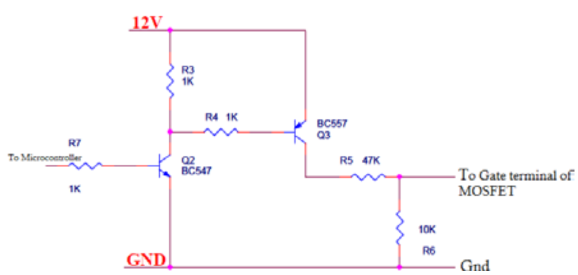

Fig. 19 Darlington Circuit

A Darlington pair is two transistors that act as a single transistor but with a much higher current gain. The amount of input current available to switch on a transistor is very low. This may mean that a single transistor may not be able to pass sufficient current required by the load. So when Darlington pair is used, it gives a vastly increased current gain when compared to a single transistor. Therefore this will allow a very low input current to switch a much bigger load current and it is essential for switching in the solar harvester.

A DC-DC Boost Converter is a power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply containing at least two semiconductor switches and at least one energy storage element. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power must be conserved, the output current is lower than the source current. Here, in our application, it steps up the low voltage generated by the solar panel to a high voltage in order to charge the battery effectively and use the harvested energy efficiently. The DC-DC Converter is designed such that its output is got according to the following equation.

$$V_o = V_{in}/((R_L/(R(1-D)))+1-D) \quad (4)$$

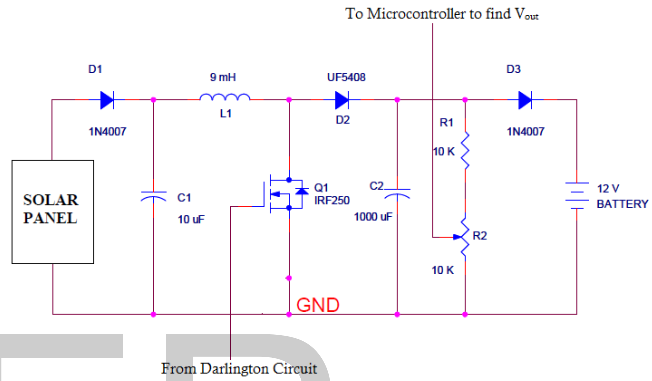

Fig. 20 DC-DC Boost Converter

The signal for IRF250 for switching purposes is taken from the Darlington Circuit. A required voltage can be assigned for the boost converter to boost up the voltage to that value. The MPPT algorithm in the Microcontroller keeps track of the boosted voltage from the DC-DC Boost converter. Once when the implementation is done the Algorithm works properly in Hardware which is displayed at the end. Thus, with Perturb and Observe Algorithm for Maximum Power Point Tracking, Optimized Solar Energy Harvester is built.

6 SERIAL COMMUNICATION AND BEST NETWORK TOPOLOGY SELECTION

The Zigbee Module used in the project is XBee Series 2 Module. The work of XBee is to perform the Serial Communication in wireless mode. Before performing Serial Communication with XBee, a thorough understanding is required about how Serial Communication takes place because of which the entire process of Serial Communication is simulated using four different softwares, namely, AVR Studio 4, HAPSIM, PuTTY and com0com. The hardware was setup after performing the simulation and the foundation for serial communication is done.

As more number of Zigbee modules are to be placed in different areas of the Forest, to cover up the whole Forest for detection, an appropriate network should be formed for the communication to take place effectively. If network is not formed with a standard and proper topology, congestion may occur which will lead to loss of sensed data. It also leads to a higher delay when improper topology is set. Also when one mote fails, the data should reach the monitoring area through a different path. So a topology that updates itself must be chosen so that the remaining motes send the sensed data properly.

OPNET Modeler 14 from OPNET Technologies Inc., USA is used to develop several networks and simulate for a specified amount of time to get results for various parameters. Depending on the results pertaining to those parameters, Best Network Topology is selected.

Network topology is the arrangement of the various nodes. Essentially, it is the topological structure of a network, and may be depicted physically or logically. Among various Network topologies available, Tree and Mesh Network topologies appear to be more stable and so, for our Network, we simulate for parameters using Tree and Mesh Network Topologies and arrive at the result as which is the Best Network Topology. The fundamental parameters for comparison include End-to-End Delay, Number of Hops and Load in bits/sec. The comparative simulation results are shown in Fig. 21, Fig. 22 and Fig. 23. In Tree topology, if the backbone fails the entire network is crippled as Tree topology is a variation of bus topology. Also maintenance of the network may be an issue when the network spans a great area.

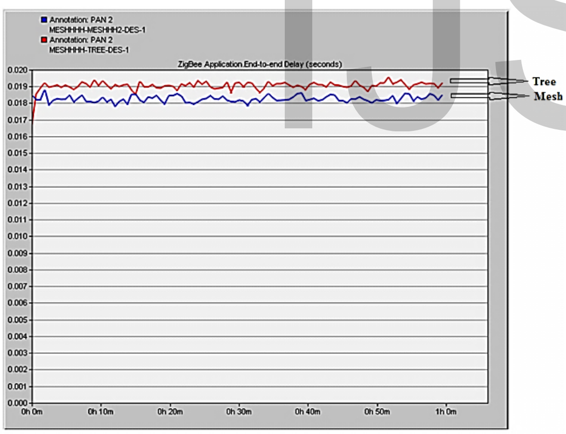

Fig. 21 Simulation Result for End-to-End Delay of Tree and Mesh Networks

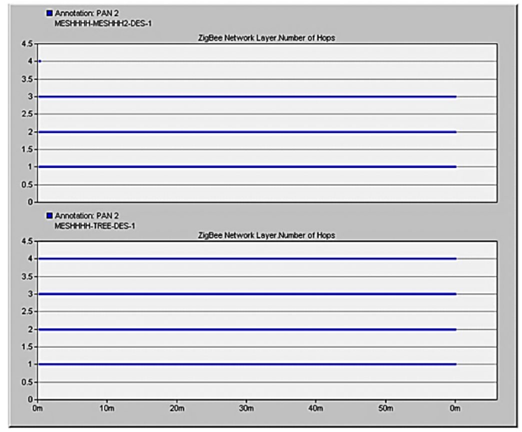

Fig. 22 Simulation Result for Number of Hops of Tree and Mesh Networks

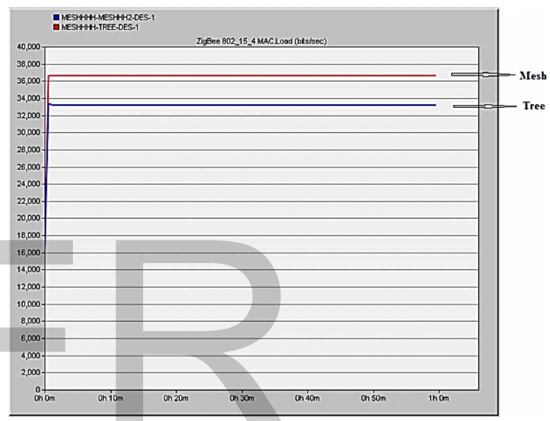

Fig. 23 Simulation Result for Load (bits/sec) of Tree and Mesh Networks

Depending upon the comparison of three different fundamental parameters shown in Fig. 21, Fig. 22 and Fig. 23 for Tree and Mesh Network Topologies, the following inferences are made.

a. Mesh Topology has less End-to-End delay according to the Simulation Result for End-to-End Delay of Tree and Mesh Networks as a packet in Mesh Topology is transmitted 0.001 seconds faster than the same packet in Tree Network Topology
b. It takes only three hops (or) jumps to reach the destination in Mesh Network Topology, whereas, it takes four hops to reach the destination for a packet in Tree Network Topology according to the Simulation Result for Number of Hops of Tree and Mesh networks. Lesser the number of hops, lesser is the packet propagation delay. So Mesh Network Topology stands taller than the Tree Network Topology according to this result.
c. Load is less in Mesh Network Topology according to the Simulation Result for Load (bits/sec) of Tree and Mesh Networks. According to the graph, the load is about 36000 bits/second for Tree Network Topology, whereas, it is about 33500 bits/second

for Mesh Network Topology. As the load becomes less, the chance of congestion will also reduce. So using Mesh Topology leads to reduced Congestion levels in the Network.

Thus, based on the above inferences, Mesh Network Topology is chosen as the Best Network Topology for forming a Network with numerous XBee Series 2 Modules in the Forest Area with respect to End-to-End delay, Hop count and Load.

7 PC-BASED WEB SERVER

A PC-based Web Server is used instead of Embedded Web Server in order to reduce the bulkiness and total cost of the System. LabVIEW is used for developing the PC-based Web Server. The front panel is designed such that it will be easy for the personnel to identify the warning as well as the type of warning. The developed front panel is shown in Fig. 24.

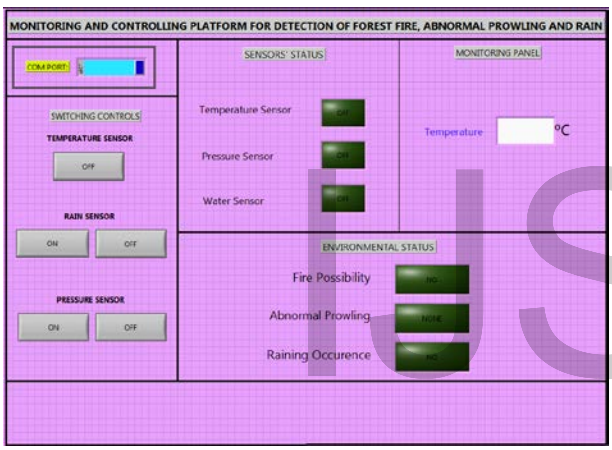

Fig. 24 LabVIEW Front Panel

Appropriate block diagram is developed which will make the front panel work according to the requirement. A typical data transfer block for temperature sensor was developed and is shown in Fig. 25. Similar blocks are created for Pressure and Rain Sensing and the server works as a whole.

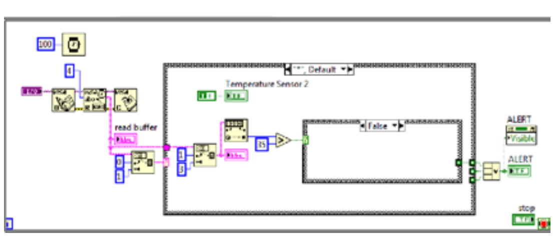

Fig. 25 Temperature Sensor Data Transfer Block

8 MECHANICAL MODELING

Mechanical Modeling must be done in a manner such that the components of the module lie intact without any damage and have the ability to tolerate any damage for its continued working. The Mechanical modeling is mainly concentrated for the Forest Area Module as it needs greater protection than the Monitoring Area Module. Mechanical modeling is done after a compact design of the module with all components contained in a small space or box yet it varies with the areas of placement.

8.1 Areas of Placement

The entire Forest Area Module comprises of three Sensors. All sensors must be arranged in such a way to satisfy for what they are meant. Considering the placement of all the three sensors for the entire forest area is not possible as detection of rain and abnormal prowling is not required for areas located deep inside the forest and for areas which are inaccessible by foot. For such areas, only temperature sensor is used along with a specially designed model that will just be put down from the choppers in inaccessible forests.

8.2 Model for Forests along the Borders

For forests which are located along the borders of areas where human life is found and for forests located slightly deep inside such areas, one type of modeling is done such that all three sensors will be implemented for the above mentioned security purposes and it is shown in Fig. 26.

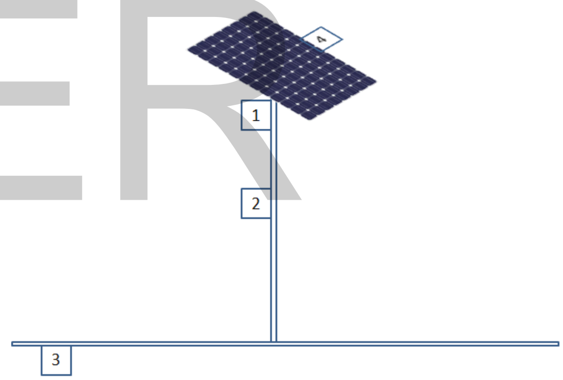

Fig. 26 Mechanical Modeling I

A pole is required to place the forest area module along with the mono-crystalline solar panel in order to make it easier for the panel to capture sunlight. The module with circuits is placed in position 1. Thermistor is placed at position 2. Pressure bag is placed at position 3 and finally the Rain Sensor is placed at position 4. All the connections pass through the middle of the hollow pole. It is seen that the module is tightly sealed to prevent it from the environmental damage. It is also noted that the antenna of the XBee module will face towards the ground from the module so that it is not damaged and that the signal strength will be high. The tube from the pressure bag which is buried slightly inside the ground connects to the pressure sensor located at position 3 along with the main module. The pressure bag is kept at a greater distance from the pole to detect trespassing. Position 2 is chosen for Thermistor due to the reason that fires spread optimally from a certain height above the ground. Even if they spread through the bottom or top of trees, an optimal detection will be made by the Thermistor when it is placed at this position.

8.3 Model for Inaccessible Forests

For the forest areas which are inaccessible by foot, the detector module is dropped from choppers or flights under very low speeds at appropriate areas with approximately equal distance of separation between adjacent modules so that it is easy to form a mesh network. If interference is more in dense forests, then a Zigbee Pro module can be used instead of normal XBee Series 2 module for covering long distances or overcoming the interference created by the forest density. For inaccessible areas of forests, only temperature sensor is required. It is attached with the module and over the module a flexible mono-crystalline solar panel is placed in the form of a cone such that the module is attached to the base of the cone. To the apex of the cone, a transparent parachute made of polythene is attached. When it is to be placed in a dense area, it is dropped from the air so that the module with solar panel will land slowly to the ground. The parachute is chosen to be a transparent one because if it is not carried away by wind, it prevents the solar panel from being exposed to sunlight. The cone shaped solar panel also helps in getting maximum light irrespective of the position of the sun during day time. Even if sunlight is diminished, the MPPT logic of the module will boost up to utilize the power effectively.

9 RESULTS AND DISCUSSIONS

The output from PC-based Web Server is the most important result of the entire project. It is vital for the monitoring area where the front panel should show the sensed information and the corresponding warning in appropriate manner. The warning produced when the temperature and pressure crosses their corresponding threshold and the corresponding changes in the Environmental Status are shown in Fig. 27. Similarly the warning produced due to the occurrence of rain is shown in the front panel and is displayed in Fig. 28. From these results, it is evident that a record of the occurrence of abnormalities in the forest environment can be easily done and immediately compared with abnormalities that occurred earlier which cannot be done with Embedded stand-alone servers as they must be connected to the PC before interpreting and comparing.

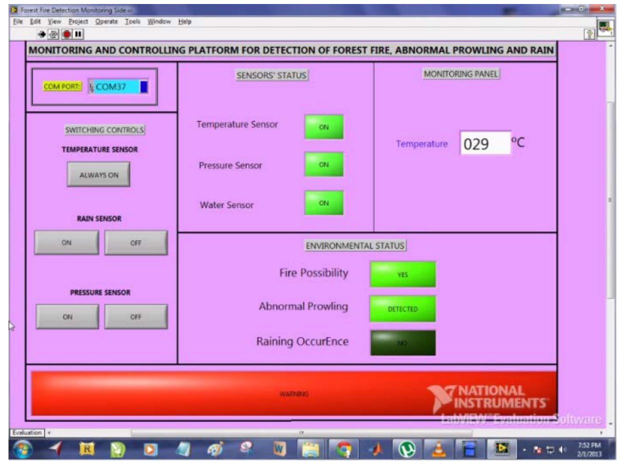

Fig. 27 Warning due to Fire and Abnormal Prowling

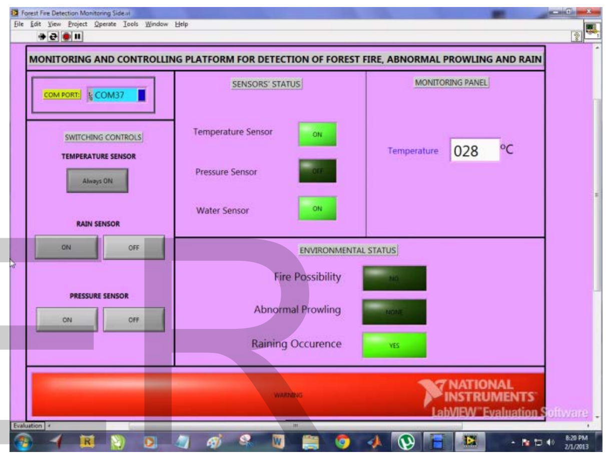

Fig. 28 Rain Warning

The warning signal displayed in Fig. 27 and Fig. 28 is the most important requirement for the personnel to know the occurrence of an abnormality. Once when the warning has occurred, the personnel can view the Environmental Status Pane in order to know the type of event that caused the warning signal to occur.

10 CONCLUSION

An advanced system for Forest Fire Detection was developed which overcomes the demerits of the Existing technologies of Forest Fire Detection. It can be ensured that the system developed can be implemented on a large scale due to its promising results. Mechanical modeling for accessible and inaccessible areas helps in the easy implementation of the Forest Area modules. The system can also be upgraded with low-power elements, higher versions of Zigbee and a novel, high-efficiency MPPT Algorithm in order to make the system run for longer periods with increased efficiency.

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