Building automation: Photovoltaic assisted thermal comfort management system for energy saving

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Abstract. Building automation plays an important key role in the means to reduce building energy consumption and to provide comfort for building occupants. It is often that air conditioning system operating features ignored in building automation which can result in thermal discomfort among building occupants. Most automation system for building is expensive and incurs high maintenance cost. Such system also does not support electricity demand side management system such as load shifting. This paper discusses on centralized monitoring system for room temperature and photovoltaic (PV) output for feasibility study of PV assisted air conditioning system in small office buildings. The architecture of the system consists of PV modules and sensor nodes located at each room. Wireless sensor network technology (WSN) been used for data transmission. The data from temperature sensors and PV modules transmitted to the host personal computer (PC) wirelessly using Zigbee modules. Microcontroller based USB data acquisition device used to receive data from sensor nodes and displays the data on PC.

1. Introduction

The position of room inside building contributes to a change of temperature inside the room since the amount of sunlight the room attains in the morning, afternoon or evening. The weather condition either rainy or hot can also affect temperature inside buildings. To overcome this problem, the air conditioning system should be controllable, thus to maintain optimum temperature inside rooms or building. Though such smart building technologies are already available, most of them are very costly to install and maintain. Many of them rendered to useless system after a short period in operation as the high maintenance cost seems as a main factor that hinders it to function. If such a system can leverage on pervasive network technology, office, computers, low cost and not specialized components, more buildings will be able to conserve more energy.

Number of techniques has been proposed in recent years for energy saving in buildings. Study shows that energy saving technologies such as efficient lighting system, double glazing windows, heating and air conditioning contribute to decrement of energy usage in office buildings [1-2]. Evaluation of the air distribution performance in building also results in reduction of energy consumption [3]. Renewable energy also plays an important role in energy saving inside building such
as solar assisted air conditioning system been used to reduce the burden by air conditioning system on the electric utilities [4].

2. System components

2.1. USB Data Acquisition Device
This device equipped with Zigbee module (Xbee Pro), temperature sensor (L35DZ) and microcontroller (PIC18F4550). Analog data from temperature sensor converted into digital values through microcontroller which then transmit the data wirelessly using Zigbee module. Influential technology of this device is USB communication protocol which been used for data transfer and power supply, so no external power and no power regulation needed. The device also offers high bandwidth data transfer which is essential for extended data transfer. Figure 1 shows the prototype of the device.

2.2. PV Module Performance Recorder
The important parameters of PV module are voltage, current and power output. This parameters need to be monitored wirelessly from host PC. A device developed using microcontroller (PIC18F452), Zigbee module (Xbee Pro) and Hall Effect current sensor (ACS712). The device capable to measure output voltage, current and power from PV module and transmits the data via wireless communication to the host PC. The device powered by 4 AA batteries. Figure 2 shows the prototype of the device.

3. System architecture
The system consists of distributed temperature sensors in each office rooms, PV system and a host PC. The polled data from temperature sensors are for room temperature profiling. The output data from PV modules monitored in order to study the feasibility of PV system for assisting air conditioning system in office buildings. The task of host PC is to monitor all data from the PV system and temperature sensors. Server-client transactions are made via wireless communication protocol. The host PC features output reading from temperature sensors and PV module, real-time graphs and a database system.

3.1. Distributed sensor real time measurement system
Real time temperature for each room needs to be monitored in order to improve the operation of air conditioning system. The system consists of sensors integrated in USB Data Acquisition Device. The device is intelligent to process the temperature values and transmit via wireless communication. The developed device is convenient as it is ‘hot pluggable’. Since the case study of this paper is for office buildings, it is assumed that each room possesses a PC. Zigbee modules used in this system is Xbee pro from Digi which capable of data transmission up to 1.5Km outdoor. Since there are many obstacles inside buildings such as doors, roof and walls, few Zigbee modules placed around the buildings in order to hop the data.
3.2. PV system
The PV system comprises of PV modules and PV Performance Recorder. PV Module Performance Recorder installed on each PV modules to record PV output parameters. The data transmitted to host PC via wireless communication using Zigbee module. The architecture for PV system wireless communication is the same as distributed sensors system.

3.3. Software and firmware
Two platforms of software are developed, which consists of embedded system coded in C (PV Module Performance Recorder and USB Data Acquisition Device) and a graphical user interface (GUI) running on host PC in order to establish interaction between user with PV output and room temperatures.

3.4. Network topology
Star, cluster tree and Mesh topology can be implemented using Zigbee technology. Since the proposed system designed for application in small office, which each sensor nodes need to pass the data to coordinator, thus star topology been used.

![Figure 3. PV module output and room temperature monitoring system block diagram.](image)

4. Testing and implementation
The proof-of-concept system illustrated in Figure 3 consisting of one PV module equipped with PV Performance Recorder device and several remote computers and one host computer equipped with USB Data Acquisition Device. The system operation only use PV module without the complete PV system since this system only monitors output from PV modules. Several phases of testing conducted for the system. The temperature reading from USB Data Acquisition Device from one room monitored
wirelessly from the host PC using a Visual Basic interface. Figure 4 shows the simple GUI developed for monitoring temperature reading inside one room. In order to test PV module wireless communication with the host PC, PV module placed at building rooftop monitored using another Visual Basic interface showed in Figure 5. The interface consists of PV module output current, voltage and power. It also shows variation of the three parameters plotted in graph. GUI shows that both parameters (room temperature and PV module output) can be monitored wirelessly from host PC.

![Figure 4. Visual Basic GUI for room temperature monitoring.](image1)

![Figure 5. Visual Basic GUI for PV module output monitoring.](image2)

5. Conclusion

In this paper, a PV module and room temperature wireless monitoring system introduced. A GUI developed using Microsoft Visual Basic environment to monitor room temperature, current, voltage and power of PV module. The results of the tests and experiments conducted indicate that this system is a promising technology to be implemented in small office building. Currently, the system only capable to monitor output from one PV module and temperature from one room. The complete system still in development. The proposed overall system should be able to utilize energy from PV to support air conditioning system in office building during peak load demand. Monitored room temperature will be used as input parameters for controllable air conditioning system in order to achieve optimum thermal conform in each room.

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