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GSM-Based Control System for Photovoltaic Stations

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ABSTRACT
Control of photovoltaic (PV) stations is essential for reliable functioning and maximum yield of any solar electric system. This paper describes the hardware and software design for PV remote control system. The system is equipped with voltage, current, temperature, humidity and irradiation sensors and GSM modem for data transmission. The use of the GSM SMS standard extends the effectiveness of the PV station independently of where the plants are placed, even far from the electrical distribution network and from the traditional and wired telecommunication systems. The designed system was built and applied on field, and satisfactory results were obtained.

Keywords
Photovoltaic station, remote control, GSM, SMS, sensor.

1. INTRODUCTION
At present, solar energy is one of the renewable energy sources, which is significantly contributing to the sustainable energy supply. It becomes attractive to emerging technology due to several distinctive advantages such as simplicity of allocation, high dependability, low maintenance and absence of noise and wear. Photovoltaic (PV) stations have recently attracted more attention as a prominent renewable energy source.

Power generation from PV stations is variable in nature due to changes in solar irradiance, temperature and other factors. In the operation of such stations especially with large size (kilowatt or megawatt scales), the station performance should be carefully monitored and a proper decision must be taken in time. For better output and performance of PV stations they should be monitored properly.

Control of PV station performance is very important for the implementation and optimum utilisation of solar energy as an electricity source. Remote control is on-line real-time monitoring and controlling the field equipment, transmitting the real-time picture and testing data to the terminal to forecast or diagnose. The remote control system should obtain, analyze, transmit, manage and feedback the remote goal information, combining the most advanced science and technology fields of communication technology and other areas. It is also the comprehensive usage of instrumentation, electronic technology and computer software.

Till now many techniques of remote control have been developed for PV stations [1-6]. These techniques involve monitoring using ZigBee network, Wi-Fi, GSM and Ethernet cable network. Remote control based on ZigBee technology is proven inefficient on a large scale because it can’t face up huge distance. Moreover, ZigBee network demands high cost and complexity. Wi-Fi offers high data rate, but this solution is suitable for microgrid local network architecture. Ethernet uses a network cable to transmit data. Hence, it is affected by geographical environment. GSM network provides a control system that is wide signal coverage, has low error rate, highly reliable data delivery, no geographical constraints and less complexity. Due to the availability of SMS the cost for data transmission becomes very low.
This paper describes the hardware and software design for PV remote control system using GSM.

2. SYSTEM DESCRIPTION
2.1. System Architecture
The overall architecture of the proposed PV remote control system is shown in Fig. 1.

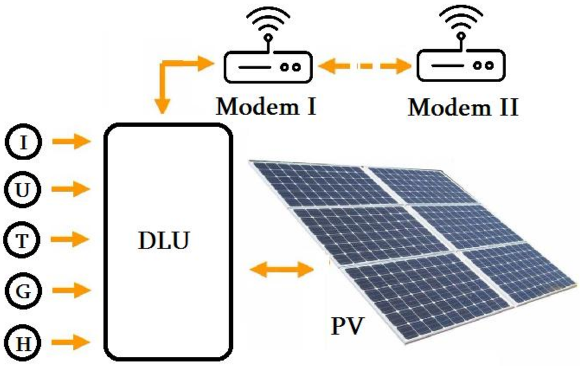

Fig. 1. Architecture of the PV remote control system

The remote control system is to identify the state of a PV station through a sensors network in order to control it remotely. The parameters required for the proper control of a PV station are: voltage (U), current (I), solar irradiance (G), ambient temperature (T) and humidity (H). All the data collected from different sensors is sent to the data logging unit (DLU). The heart of the DLU is a microcontroller, through which data is converted from the analog to a digital form in the processing.

The information from the sensors is transmitted via the GSM network using the SMS. The SMS service was favored, because it is remarkably simple and cheap. SMS can contain 160 alphanumeric characters. These characters can be coded for security reasons or they can be directly utilized as data as per the requirements. One major advantage of SMS is that it is supported by 100% GSM mobile phones. Generally the message delivery takes 0,5÷2 s depending on the momentary traffic on the network [7].

The information from the sensors goes to the DLU where it is processed and passed by an RS 232 or USB interface to the GSM Modem I (SIM card), and later sent to a connected remote PC or Mobile Phone by GSM Modem II after a specific interval of time. Received data are monitored by the software and displayed on PC monitor or mobile phone screen. System can send alerts and status messages to the control center or user. The DLU, other than sending the SMS to any desired SIM of mobile phone of user or control center, can also take the preliminary action to shut down one unit either of its own or by an instruction received from a return SMS.

2.2. Hardware Design

GSM Modem. F2003 modem is a kind of cellular terminal device that provides the SMS function by the public GSM network. It adopts a high-powered industrial 16/32 bits CPU and an embedded real-time operating system. It supports RS232 and RS485 (or RS422) ports that can conveniently and transparently connect one device to a cellular network. Mode for usage of GSM modem in this research will be text mode.

Sensors. The choice of sensors depends on interfacing it with microcontroller, the design should simplify the I²C (Inter-Integrated Circuit) modification of the role of a node by simply adding or modifying or suppressing a sensor. A better solution for that would be to use digital sensors with I²C communication port [8]. In the light of the above -mentioned we selected the following sensors:

• SFH 5712 solar irradiance sensor detects ambient brightness in the same way as the human eye and offers high speed rates of up to 3.4 MHz. With 150 μA during operation and only 1.5 μA in stand-by mode, the sensor consumes extremely little power.

• SHT21 humidity and temperature sensor utilizes a capacitive sensor element to measure humidity, while the temperature is measured by a band gap sensor. Relative humidity operating range: 0-100% RH (resolution of 0.03%), and temperature operating range: -40 to +125°C (resolution of 0.01°C).

• LV 25-P voltage and LA 25-NP multi-range current transducers provide easy to use precision voltage/current measurements.

Microcontroller. AVR Atmega microcontroller is featured by:

• Thirty two 8-bit general purpose registers.

• 64k bytes of in-system programmable flash memory, 512 bytes of EEPROM and 1 byte of internal SRAM.

• 10 bit in-built and six channel analog to digital converter (ADC).

• On chip analog comparator.

The power supply of the microcontroller, sensors and GSM modems is a battery powered from PV station. This power supply must guarantee that all the electronic circuitry is correctly supplied from the PV station even under low or no irradiation conditions. Although it is obvious that, as far as energy production is concerned, no useful information will be delivered during the night, the system is still operating when the sun is gone for safety purposes—protection against possible theft of the PV panels. In the same way, all the circuitry will be switched off during the idle periods to reduce consumption.

2.3. Software Design

In software design we have used the C programming language to program the microcontroller. The microcontroller is then interfaced with the GSM module. AT commands are instructions used to control a modem. Few GSM AT commands that are used for specific operations are: AT = Initialize Modem; AT+CMGF=1 = Set Modem in Text Mode; AT+CNMI = New Message Indicator; AT+ECHO = Turns Echo On/Off; AT+CMGS = Send Message; AT+CMGR = Read Message; AT+CMGD = Delete Message These are the few commands for F2003 GSM IP modem which will do our task.

The message is constituted in the form of a packet whose structure is not a common one. It ignores any unauthorized message or even any other messages from the user, which are not in their packet format. The desired SIM numbers are pre-loaded within the memory of DLU. Here the tradeoff is that if any abnormality is detected then only the SMS using GSM modem will be sent to the pre-loaded SIM numbers and can wait for any return SMS for any necessary action to perform. To make the SMS more secure and efficient data coding techniques can be adopted.

The microcontroller algorithm was shown in Fig. 2.

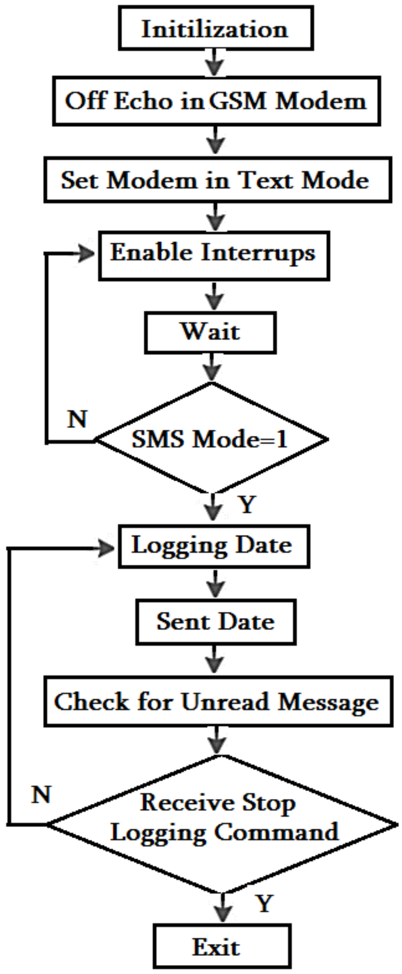

Fig. 2. Microcontroller algorithm

The first stage is the initialization of microcontroller. Next, AT command was used to switch off the echo function in GSM Modem to easily identify the feedback from the modem. AT+CMGF=1 command is sent to enable GSM Modem I to operate in text mode. Then, interrupts are enabled if any text is received. After that, the microcontroller will wait for a command from GSM Modem II, which will be sent from a PC or mobile phone. If GSM Modem I received a text message, the microcontroller will start logging data. If not, the microcontroller will continue waiting until it receives a command. Microcontroller will log data and send SMS to GSM modem II. Then, it will check for any unread messages. If it receives a stop logging command from GSM Modem II, it will exit the system and keep in standby mode. If not, it will continue to control until it receives a stop command.

2.4. Implementation and Testing

Developed remote control system was tested at a demonstration PV station with an installed capacity of 5.0 kWh in Barva Innovation Center (Talin, Aragatsotn marz) (Fig. 3). A multiple sensors and actuators are placed in different locations in the station to monitor and control the PV station operation.

Fig. 3. Demonstration PV station

As an illustration Fig. 4 shows daily variations of ambient temperature T, solar irradiation G, voltage U and current I of the demonstration PV station, which are displayed based on the provided control using GSM. The sampling time was selected for 5 second so as to capture the sudden change in weather that is sometimes required for further analysis.

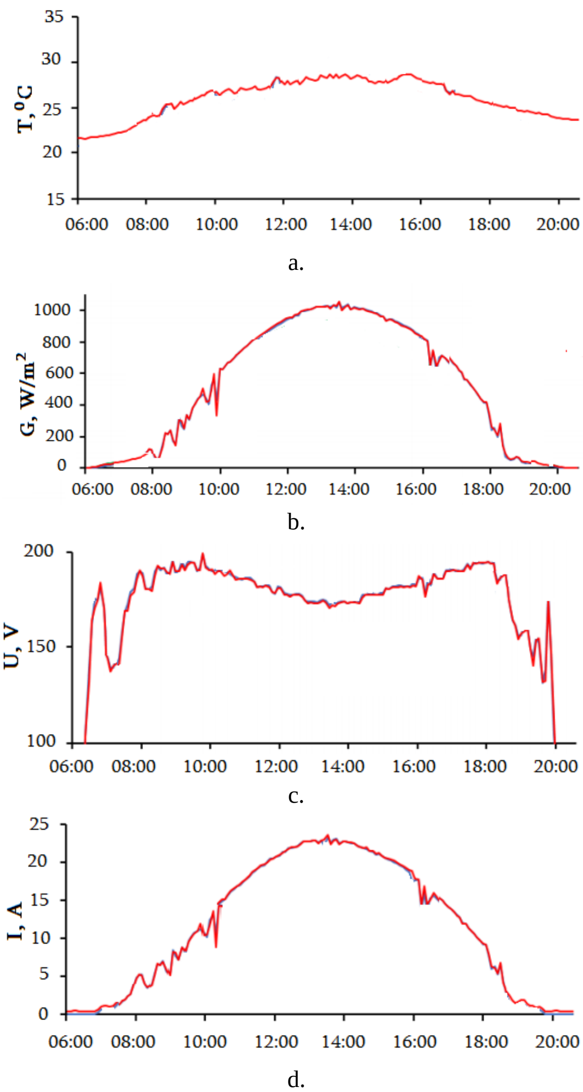

Fig. 4. Daily variations of ambient temperature (a), solar irradiation (b), voltage (c) and current (d) of PV station

The results of the testing depict that the remote control system operates well under the severe conditions without any data loss and transmission delay.

The proposed control system can also be applied to find the maximum power point of a PV station, check the range of electrical power generation and compare the results with the expected manufacturer's data-sheet values [9]. All monitoring data are monitored as real-time data, therefore the user can also evaluate the system situation in the current states and make decisions to take an immediate action if needed. This control system can be further equipped with GPS modules for tracking PV station locations when deployed in large numbers that will further enhance the operation and maintenance of the stations in real time.

3. CONCLUSION

GSM-based remote control system was designed, emulated, implemented, and experimentally tested. This system eases the control of a PV station placed at a remote area. GSM is preferred over other techniques due to its highly reliable data transmission and its cost. The control system is working properly in all conditions. It can be efficiently used in the new utility-scale PV stations in Armenia.

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