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GSM Based Automated Embedded System for Monitoring and Controlling of Smart Grid

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Abstract**—**The purpose of this paper is to acquire the remote electrical parameters like Voltage, Current, and Frequency from Smart grid and send these real time values over GSM network using GSM Modem/phone along with temperature at power station. This project is also designed to protect the electrical circuitry by operating an Electromagnetic Relay. The Relay can be used to operate a Circuit Breaker to switch off the main electrical supply. User can send commands in the form of SMS messages to read the remote electrical parameters. This system also can automatically send the real time electrical parameters periodically (based on time settings) in the form of SMS. This system also send SMS alerts whenever the Circuit Breaker trips or whenever the Voltage or Current exceeds the predefined limits.

Keywords**—**GSM Modem, Initialization of ADC module of microcontroller, PIC-C compiler for Embedded C programming, PIC kit 2 programmer for dumping code into Micro controller, Express SCH for Circuit design, Proteus for hardware simulation.

I. Introduction

THE time complicated interlocking and operation controlling requirements usually noticed in the Smartgrid working, which lead to necessity of automation of the undergoing process. In this respect, Smartgrid automation, which is the creation of a highly reliable, self-healing power system that rapidly responds to real time events with appropriate actions, ensures to maintain uninterrupted power services to the end users.

II. Proposed Method

This research paper aims at continuously monitor the load conditions of the Smartgrid. It also monitors the temperature of the devices present in the Smartgrid. If the load increases beyond the Smartgrid's rated capacity, the microcontroller will automatically shut down the Smartgrid and intimates the same to the operator by sending a message through a GSM modem. A modem provides the communication interface. It transports device protocols transparently over the network through a serial interface. A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves. If the temperature of the Smartgrid increases, then the microcontroller will automatically starts the cooling system for the Smart grid. At any point, if the operator wants to know the loads conditions and the temperature, he has to send a predefined message to the modem which is interfaced with the microcontroller and the controller acknowledges the operator with the required information.

1. Sensing different electrical parameters (voltage, current, temperature).
2. Forwarding the electrical parameters over GSM network.
3. Producing buzzer alerts (if necessary).
4. Automatic circuit breaking operation.

An embedded system is a combination of software and hardware to perform a dedicated task. Some of the main devices used in embedded products are Microprocessors and Microcontrollers. Microprocessors are commonly referred to as general purpose processors as they simply accept the inputs, process it and give the output. In contrast, a microcontroller not only accepts the data as inputs but also manipulates it, interfaces the data with various devices, controls the data and thus finally gives the result.

The research paper GSM Based Embedded System for Smartgrid Monitoring and Control System using according to the instructions given by the above said microcontroller. Distributed transformers are prone to damages due to the rise in oil temperature when there is an overload or huge current flows through the internal winding of the transformer. When the oil temperature rises, it increases the probability of getting damages in the transformers. The transformers are to be monitored very cautiously during these situations. The proposed system consists of a monitoring unit that is connected with the distribution transformer for the purpose of monitoring the same. Hence, we introduce a simulation model which details the operation of the system to rectify the mentioned problem. The monitoring system is constituted by three major units, namely,

1. Data processing and transmitter unit
2. Load and Measurement Systems
3. Receiver and PC display unit

We have designed a system based on microcontroller that monitors and controls the voltage, current and oil temperature of a distribution transformer present in a Smartgrid. The monitored output will be displayed on a PC at the main station that is at a remote place, through RF communication. The parameters monitored at the distribution transformer are compared with the rated values of the transformer. Additionally the breakdowns caused due to the overload and high voltage are sensed and the signals are transmitted to the main station using RF communication. The software in the PC compares the received values with the rated measurements of the distribution transformer and shuts down the transformer so

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that it can be prevented from damages and performances can be enhanced quiet to a remarkable level. The controller consists of a sensing unit which collects the essential parameters such as current, voltage and the oil temperature within the distribution transformer. The digital display connected to the processing unit displays corresponding parameter values at the Smartgrid for any technical operations. The controller also senses the overload and high current flow conditions in the internal windings that may lead to breakdown of the corresponding unit. The microcontroller is programmed in such a manner so as to continuously scan the transformer and update the parameters at a particular Time interval. The parameter values sensed by the microcontroller are transmitted through the RF transmitter connected to the microcontroller unit. The transmitted signals are received at the main station using the RF receiver. The received signals are then passed to the PC. The software loaded in the PC is used to monitor the changes in the parameters that are measured from the distribution transformer. When a remarkable change is noticed in the measured values it controls the unit by ending it from any serious damages.

The values of voltage, current and temperature of the transformer is directly applied to Port A (one of the input ports of the microcontroller). Along with this, a display is connected in the Port B (another input port of the microcontroller). The RF transmitting section and the load variation control are connected to the Port C (one of the output ports in the microcontroller).

The monitoring PC is connected to the main station. The microcontroller at the Smartgrid monitors and captures the current, voltage and temperature values for a particular period of time interval. The captured values are stored in the data register and displayed using the LCD display.

The monitored voltage, current and temperature values of the transformer are transmitted using the RF transmitter for each and every time interval. Any antenna tuned for the selected RF frequency can be utilized for the transmission of the RF signal but the antenna has to exhibit a unidirectional radiation pattern. In the receiver side of the proposed system, the receiver antenna converts the RF signal into electrical signal and acquires the information which has been transmitted by the transmitter. Based on the received information, controlling operation is performed. If the receiver receives the transformer parameters which is greater than the fixed threshold level, then immediately the units is shutdown so as to protect the same. The voltage level is reduced using transformers and power is transferred to customers through electric power distribution systems. Power starts from the transmission grid at distribution Smartgrid where the voltage is stepped-down (typically to less than 10kV) and carried by smaller distribution lines to supply commercial, residential, and industrial users. Novel electric power systems encompassing of power transmission and distribution grids consist of copious number of distributed, autonomously managed, capital-intensive assets.

A. Real Time System Design

Real time systems have to respond to external interactions in a predetermined amount of time. Successful completion of an operation depends upon the correct and timely operation of the system. Design the hardware and the software in the system to meet the Real time requirements. Designing real time systems is a challenging task. Most of the challenge comes from the fact that Realtime systems have to interact with real world entities. These interactions can get fairly complex. A typical Realtime system might be interacting with thousands of such entities at the same time. Real time Response, Recovering from Failures, Working with Distributed Architectures, Asynchronous Communication, Race Conditions and Timing

B. Architecture and Working of GSM Networks

A GSM network consists of several functional entities whose functions and interfaces are defined. The GSM network can be divided into following broad parts. The Mobile Station (MS), The Base Station Subsystem (BSS), The Network Switching Subsystem (NSS), The Operation Support Subsystem (OSS). The added components of the GSM architecture include the functions of the databases and messaging systems: Home Location Register (HLR), Visitor Location Register (VLR), Equipment Identity Register (EIR), Authentication Center (AuC), SMS Serving Center (SMS SC), Gateway MSC (GMSC), Chargeback Center (CBC), Transcoder and Adaptation Unit (TRAU)The MS and the BSS communicate across the Um interface, also known as the air interface or radio link. The BSS communicates with the Network Service Switching center across the A interface.

In a GSM network, the following areas are defined:

Cell: Cell is the basic service area: one BTS covers one cell. Each cell is given a Cell Global Identity (CGI), a number that uniquely identifies the cell.

Location Area: A group of cells form a Location Area. This is the area that is paged when a subscriber gets an incoming call. Each Location Area is assigned a Location Area Identity (LAI). Each Location Area is served by one or more BSCs.

MSC/VLR Service Area: The area covered by one MSC is called the MSC/VLR service area.

PLMN: The area covered by one network operator is called PLMN. A PLMN can contain one or more MSCs.

C. Debugging Tolls

Embedded debugging may be performed at different levels, depending on the facilities available. From simplest to most sophisticate they can be roughly grouped into the following areas [1], [2]:

1. Interactive resident debugging, using the simple shell provided by the embedded operating system (e.g. Forth and Basic)
2. External debugging using logging or serial port output to trace operation using either a monitor in flash or using a debug server like the Remedy Debugger which even works for heterogeneous multi core systems.

3. An in-circuit debugger (ICD), a hardware device that connects to the microprocessor via a JTAG or Nexus interface. This allows the operation of the microprocessor to be controlled externally, but is typically restricted to specific debugging capabilities in the processor.
4. An in-circuit emulator replaces the microprocessor with a simulated equivalent, providing full control over all aspects of the microprocessor.
5. A complete emulator provides a simulation of all aspects of the hardware, allowing all of it to be controlled and modified and allowing debugging on a normal PC.
6. Unless restricted to external debugging, the programmer can typically load and run software through the tools, view the code running in the processor, and start or stop its operation. The view of the code may be as assembly code or source-code. [2]

Because an embedded system is often composed of a wide variety of elements, the debugging strategy may vary. For instance, debugging a software (microprocessor) centric embedded system is different from debugging an embedded system where most of the processing is performed by peripherals (DSP, FPGA, and co-processor). An increasing number of embedded systems today use more than one single processor core. Embedded development makes up a small fraction of total programming. There are also a large number of embedded architectures, unlike the PC world where 1 instruction set rules, and the UNIX world. Where there are only 3 or 4 major ones. This means that the tools are more expensive. It also means that they're lowering featured, and less developed. On a major embedded project, at some point you will almost always find a compiler bug of some sort. Debugging tools are another issue. Since you can't always run General programs on your embedded processor, you can't always run a debugger on it. This makes fixing your program difficult. Special hardware such as JTAG ports can overcome this issue in part. However, if you stop on a breakpoint when your system is controlling real world hardware, permanent equipment damage can occur. As a result, people doing embedded programming quickly become masters at using serial IO channels and error message style debugging [3].

III. Block Diagram of the Proposed Research Paper

The circuit was designed using electronic workbench software. This software was used to design a sample for the power supply which was incorporated on the receiver system. The receiver sections were designed by this computer aid. In designing the power supply, the software has a menu that contains the various components of the circuit. One has to identify which menu contains the component for the power supplies were selected. The components that were selected are: diodes (1n4001) capacitor (220μF and 10μF) and regulator 7805. A step down transformer of 240/12V AC Was also selected was also selected. These components were laid out and their pins were joined appropriately with lines. These lines are similar to the conductors on the printed circuit board (PCB). The same procedure was followed in the design of the receiver circuit. The receiver was constructed on printed circuit board (PCB) of 30mm x 14mm x 1.5mm dimensions. The PCB was etched in accordance with the receiver circuit shown below with various integrated circuit (IC) pin hole drilled. The microcontroller chip PIC16F877A, circuit breakers and the relays were all inserted on the board to form a complete receiver unit. The implementation of the system involves two steps which are: Setting up the system and inter facing with graphic user interface (i.e. application software). The application software for the system has been developed by using a high lever language C-programming debugger. The debugger contains a high speed simulator and a target debugger that let you simulate an entire PIC16F877A system including on chip peripherals [4] [5].

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refers to magnetic flux density B or magnetic field strength symbolized as $\mu_0 H$. Use the center dot to separate compound units, e.g., “$A \cdot m^2$.”

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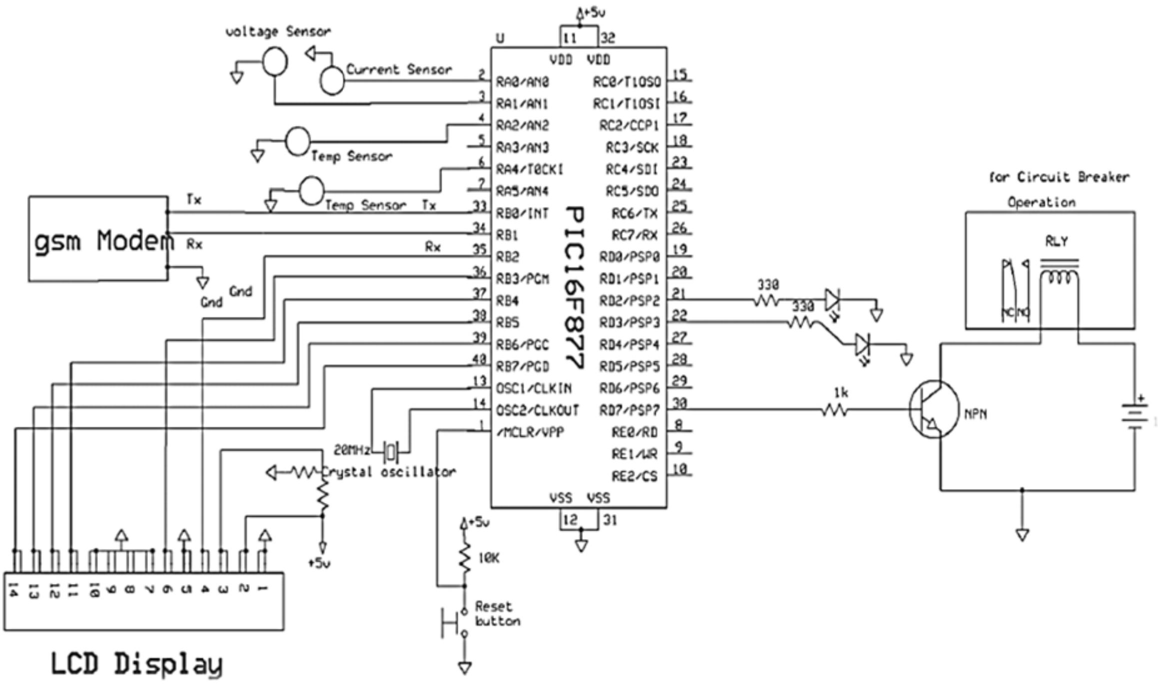

Fig. 1 Schematic diagram

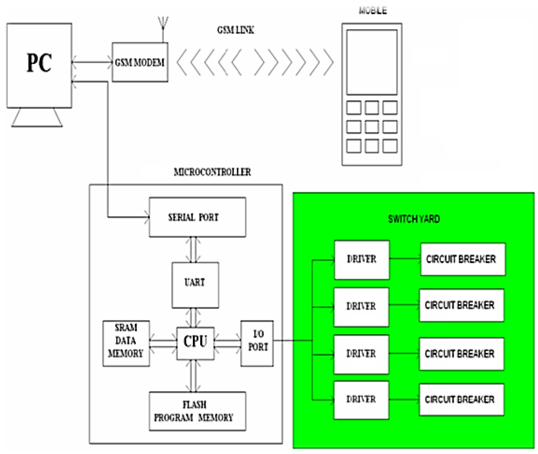

Fig. 2 Communication System

IV. Working Principle

The system was tested by connecting a GPRS modem and RS232 cable to the PC. The RS232 cable is connected to microcontroller PIC16F877A through an interface MAX 232Ic. The microcontroller PIC16F877A is connected to the circuit breaker through a relay. When the circuit is powered by connecting it to 240 V AC supply, the incoming AC voltage is rectified by bridge rectifier. The voltage is then reduced to 5V by a regulator which serves as an input to the microcontroller. The system was tested manually by pressing a knob on the software to activate the circuit breaker. Secondary, the system was tested remotely by sending an SMS message to the GPRS or modem through the PC to RS232 cable to the microcontroller PIC16F877A and it also worked. Below is the screen shot of the system control Panel with circuit breakers turned ON. Thus the automation of electrical power Smartgrid is designed and implemented using GSM technology [6]. This brings out the efficient way of power transmission and distribution in electrical Smartgrid though it is carried out using wireless mobile communication technology. AT commands are used to communicate the GSM modem and the microcontroller. Cellular phones have been invading all over the globe. Cellular phones enable people to communicate over a wide area by using a network of radio antennas and transmitters arranged in small geographical area called cells. By using a rooming facility provided by cellular phone providers, communication could be effective wherever you are on a globe. Technology can explore more benefit on the utilization of cellular phones. The GPRS was able to read the data sent by cell phone at a frequency of 900MH. The GPRS uses packet switching method to transfer data, which means that data is sent over the time, which has less traffic. The microcontroller PIC16F877A is a low power, high performance CMOS 8-bit computer. It provides high-flexible and cost effective solution to the control applications. The above schematic diagram GSM Based Embedded System for Smartgrid Monitoring and Control System explains the interfacing section of each component with micro controller and GSM module. [6]

The crystal oscillator connected to 13th and 14th pins of micro controller and Regulated power supply is also connected to micro controller and LED's also connected to micro controller through resistors and motor driver connected to micro controller.

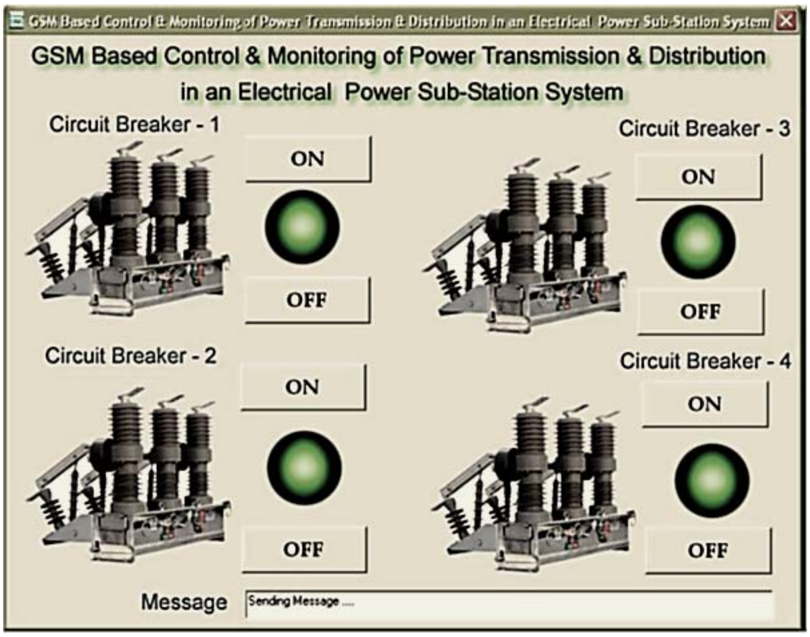

Fig. 3 Screen shot of control Panel with circuit breakers turned ON

V. Scope of the Research

Our research paper "GSM Based Embedded System for Smartgrid Monitoring and Control System" is mainly intended to operate the devices like fans, lights, motors etc.., through a GSM based mobile phone. The system has a GSM modem, temperature, current, voltage sensors and the devices to be operated through the switches like Relay which are interfaced to the microcontroller. The micro controller is programmed in such a way that if a particular fixed format of SMS is sent to GSM modem from mobile phone, which is fed as input to the microcontroller which operates the appropriate devices. A return feedback message will be sent to the mobile from GSM modem. The temperature at the place where devices are being operated can be known. In future we can use this research paper in several applications by adding additional components to this research paper. This research paper can be extended by using GPRS technology, which helps in sending the monitored and controlled data to any place in the world. The temperature controlling systems like coolant can also use in places where temperature level should be maintained. By connecting wireless camera in industries, factories etc. we can see the entire equipment from our personal computer only by using GPRS and GPS technology. The monitoring and controlling of the devices can be done from the personal computer and we can use to handle so many situations. By connecting temperature Sensor, we can get the temperature of dangerous zones in industries and we can use personal Computer itself instead of sending human to there and facing problems at the field. The temperature sensor will detect the temperature and it gives information to the micro controller and micro controller gives the information to the mobile phone from that we can get the data at pc side.

VI. Result

The research paper designed such that the devices can be monitored and also controlled from anywhere in the world using GSM modem connected to mobile phone. The proposed system which has been designed to monitor the transformers essential parameters continuously monitors the parameters throughout its operation. If the microcontroller recognizes any increase in the level of voltage, current or temperature values the unit has been made shutdown in order to prevent it from further damages. The system not only controls the distribution transformer in the Smartgrid by shutting it down, but also displays the values throughout the process for user's reference. This claims that the proposed design of the system makes the distribution transformer more robust against some key power quality issues which makes the voltage, current or temperature to peak. Hence the distribution is made more secure, reliable and efficient by means of the proposed system.

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