Remote Sensing and Control of Various Electrical, Atmospheric Parameters in Large Scale Industries

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Summary
The industry for manufactured goods increases extensively worldwide in recent years to fulfill the demands from the human beings. Numbers of large scale industries have grown folds in the recent past. Remote sensing and controlling of parameters in industries increase the performance and also can reliably preempt machine failure and diagnose the cause thereby in a position to take immediate corrective action before the failure occurs. This system collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data. The aim of this paper is to develop a RTU system to monitor electrical parameters like Voltage, Current and Temperature, and pass on the data to a supervisory subsystem. Software controlled computer monitors the data and control a Relay for switching action. The monitored data is stored in a database for further action. In order to make things simpler and easier to man we have come up with idea of SCADA[2], which has even database which is advantageous.

Key words: SCADA, Supervisory control, Data Acquisition, Sensors, RTU system

1. Introduction

Supervisory Control and Data Acquisition (SCADA) [4] Systems are computer-controlled, human-monitored systems for collecting and analyzing data. It controls the configuration and actions of real-time process control systems. Such systems are used in geographically distributed utilities such as electrical power grids, gas pipelines, electrical power transmission and distribution, water treatment plant, petrochemical refining etc. Since they deal with real-time events, the hardware and software configuration of the this system must be highly reliable with the sensors, device controls, alarms, etc.

This system mainly consists
- Human-Machine Interface (HMI)
- Remote Terminal Units (RTU)

Human-Machine Interface (HMI) which presents process data to human operator and controls the process. It is basically a Computer system with front-end controls with the relevant Software and a Database.

Remote Terminal Units (RTUs) connect various sensors and digitize them to send it to the supervisory system. Many times PLCs (Programmable Logic Controller) are used as RTUs. Additionally a communication channel is required to connect to the supervisory system. The remote terminal unit (RTU) is actually the data acquisition unit. The RTU collects data from the respective process sensors regularly.

The Features of this paper are
- Monitoring and Controlling is at a time
- Makes simple system to more sophisticated
- Makes open system to closed control system
- Calculation of losses is easy
- Planning makes easy as it has backup of real time values
- Relative and active power can be calculated

This remote sensing and control system can be used in various applications like Power station, Manufacturing unit, and Water treatment plant etc.

1.1 Power Station

![Fig. 1 Power station](image)
Figure 1 shows the typical power station. This setup plays an important role in power transmission and distribution, electrical grids, energy control and distribution. Here the electrical parameters like Voltage, Current, Temperature, Phases of respective are acquired, monitored and controlled. This helps in load shedding, load distribution and planning of power system. By this tool we can have a clear picture of Input and Output ratio so that load balance can be done. Even it acts as security tool in avoiding losses, leakage and power theft. Totally it enhances the HMI (Human Machine Interface) to another level which makes very simple and easy.

1.2 Manufacturing plant

This plays an important role in manufacturing unit on the field of production management. It collects the number of units produced from different lines and according to it; it sets the conveyor speed of assembly line such that it maintains the production cycle balanced. This tool makes the job of line supervisor easy. Figure 2 shows the manufacturing plant.

![Fig. 2 Manufacturing Plant](image)

2. Hardware implementation

The Block diagram of the hardware implementation of the entire system is as shown in the Figure 3. All the major subsystem blocks are shown with their inter connections to each module. The block diagram consists of two major subsystems like remote terminal unit and Supervisory system. The detailed discussions of the components used in the system are explained below.

![Fig. 3 The Block diagram](image)
2.1 Remote terminal unit

The RTU design is based on a programmable device. The Microcontroller can easily be programmed. Here we have used two microcontrollers. There are two communication channels provided between the RTU and the supervisory Subsystem. The two channels are serial RS232 and wireless RF link. The required channel is selectable by a switch by the user. The RF link (Radio frequency) at 315 MHz is used for wireless mode of data transmission from and to the Supervisory system. The data is encoded and sent through RF link. Similarly the received at the RF receiver is decoded for further processing. A 16 x 2 lines LCD display is provided to indicate data acquired. We have the following sub systems in the RTU Microcontroller, DC regulated Power Supply, RF Transmitter module and RF Receiver module, Selection of RF or serial link mode.

2.2 Supervisory system

The sub systems in the Supervisory System used are Microcontroller, DC regulated Power Supply, RF Transmitter module and RF Receiver module, Selection of RF or serial RS232 link to Computer.

3. Components or Subsystems Description

3.1 Microcontroller circuit (AT89S52)

It is the heart of the system which controls all the activities of transmitting and receiving. The IC used is AT89S52. The AT89S52 Microcontroller [3] is an 8-Bit microcontroller with 8K Bytes of In-System Programming Flash Memory. The Microcontroller is placed in a Printed circuit Board with all the port pins are brought out as connector pins. The frequency of operation of the Microcontroller is determined by the Crystal connected between pins 18 and 19. In this project we have used 11.059 MHz.

3.2 Power supply circuit

The Controller requires +5 Volts DC Supply as VCC for its operation. This is obtained by a DC regulated Power supply circuit which works on Mains 230 VAC supply. The DC Power required to the Microcontroller is drive with regulated circuit provided on the PCB itself. The suitable bypass capacitor (0.1 μfarad) is connected between pins 40 (VCC) and 20 (GND). We use regulator ICs 7805 and 7812 for +5V and +12V respectively. The DC regulated power supply is used to get +5 VDC as VCC for Microcontroller and the Relay coil operating voltage (+12 VDC). It is a linear DC regulated Supply drive from the mains 230 VAC.

The supply consists of a Step-down transformer (TR4), Rectifier, Filter and Voltage regulators. The transformer has a secondary voltage of 0-12 volts at 1A rating. It is rectified by a Bridge rectifier (W06M) and a Filter capacitor (2000 μf) to remove the ripple contents. A fixed DC voltage regulator of Type LM7812 and LM7805 are used to get Dc voltages +5 and +12V. These regulators take care of any mains variations and still supply the fixed voltage. There are LEDs with current limiting resistor (2.2 K) to indicate the presence of the DC voltages. High frequency interferences are avoided by using 0.1 Microfarad Capacitors. The Voltage Regulators are built in short circuit protection against any accidental shorting of the output terminals. Heat sink is provided for the 12 Volts power supply for air cooling.

3.3 Analog to digital converter

Three Analog to digital converters are used for digitizing the sensor output like Temperature, Voltage and current so that it is compatible to controller for further operations.

3.4 Relay Driver circuit

A relay is used to show a load switching ON or OFF. A relay is switched ON to connect any load. The Relay used is a 12 Volt coil relay with coil resistance of around 180 ohms. It is a 2 pole, 2 way contact terminals for 230 VAC, 5 Amps rating. The switching ON / OFF of the relay is carried out by the Microcontroller (Program) through relay driver circuit. The Relay drive circuit consists of an Opto-coupler, inverter and a relay driver, connected to the relay coil.

The Relay coil requires a DC voltage of +12 Volts and its coil resistance is around 180 Ohms. Hence the coil current is around 600mili amps. The Microcontroller pin will not be able to drive a relay directly as it cannot supply sufficient current. Thus a relay driver, ULN2004A IC [10] is used to drive the relay. The ULN2004A can drive a coil by providing a maximum current of 500ma.

Whenever an inductive load (like relay Coil, Motor coil, etc) are switched ON and OFF, its switching spikes can affect the low voltage devices like Microcontroller. To avoid the interferences, an opto-coupler circuit is introduced in the relay drive circuit. The relay drive circuit is connected to the Microcontroller pin 27. Whenever the drive pin is at Logic High condition, the photo diode in the opto-coupler will be reverse biased. Because of lack of base signal, the photo transistor will be in OFF condition. The emitter voltage will be zero. The next stage transistor (BC547) will be in cut-off state. Hence the input pin 1 of the ULN2004A is at
logic 0. The output pin 16 of the ULN2004A connected to the relay coil, will be at logic High (due to the inversion logic in ULN2004A). Thus the Relay goes to OFF condition, that is the relay Common terminal and NC connected as usual.

Whenever the Microcontroller wants to switch ON the relay, the pin 27 will be driven to logic Low. The opto-coupler diode will be forward biased and the photo transistor will be ON, because it gets sufficient base signal. A current limiting resistor of about 270 ohms (current should be more than 10milli amps) is used in the photo diode circuit, so as to send sufficient coupling signal at the base of the phototransistor. The logic voltage coming from the microcontroller is converted to +12 Volt level at the photo transistor. The +12 V level is required for the Relay coil. The main use of Opto-coupler is to avoid back EMF and to isolate power circuit and control circuit.

Now the emitter will be at around +12 volts, which drives the transistor BC547 to saturation. Hence the Pin 1 of the ULN2004A will be around +12 volts. Because of the inversion in ULN2004A, the pin 16 of the IC goes to logic 0. This drives the Relay to ON condition. A freewheeling diode is required to be connected in reverse condition across any relay coil. This is to provide a current path, in case the relay is switched off from ON condition. The free wheeling diode is already built inside the ULN2004A. An LED with a current limiting resistor of 4.7 k is connected across the relay coil to indicate the ON condition of the. All the resistors used in the circuit will limit the current as per the data sheet of the components like MCT2E, BC547 and ULN2004A.

3.5 Reset circuit

A circuit with Resistor (10 K) and Capacitor (10 microfarad) combination is included as a reset circuit for the Microcontroller at Pin 9. The reset condition is also indicated trough a LED. The Reset is required to address the memory at 00H location at the Power ON condition. Port 0 is provided with Pull up resistors of the value 10 K (SIP Package).

3.6 RF transmitter module

The RF (Radio Frequency) Transmitter module is required here to wireless mode of transmitting all the gathered parameters (Temperature, Voltage and current) to the supervisory system. The RF (Radio Frequency) transmitter circuit consists of an Encoder IC and an RF transmitter module. The RF Transmitter module works at 315 MHZ frequency and is of model FS 1000A. It is a 3 Pin module (Pins for VCC, GND, data) with about 10 mW power output, working voltage range 3 to 12 volts. It has a small antenna attached.

The Encoder is an IC HT12E [11], which has input as 8 bit address and 4 bit data. The data to be transmitted is coming from microcontroller. The address is fixed here. These are encoded in the Encoder and given to the RF transmitter module as serial data for transmission. The RF module and an Encoder IC are used in the project. It is a Vega kit make model type. It requires a resistor of 470 K Ohms between pin 15 and 16 to get the clock for transmission. A bypass capacitor of 0.1 microfarad is connected between VCC and GND to bypass any high frequency interference. The

3.7 RF Receiver module

The RF (Radio Frequency) Receiver circuit consists of a Decoder IC and an RF Receiver module. The RF Receiver module works at 315 MHZ frequency and is of model PCR2A. It is a 3 Pin module, working voltage at 5 volt DC. It has a small antenna attached with it for sufficient range.

The Encoder is an IC HT12D[11], which has input as 8 bit address and 4 bit data. Encoders are used to specify the unique address so as to avoid jamming. It’s also called as anti jammers. The RF receiver module receives data serially and the data is passed on to the decoder through pin 14 (Din). These are decoded and given to the Microcontroller as 4 bit data. The Pin 17 of the decoder is connected to the interrupt pin 13 (INT1) of the microcontroller. It indicates the arrival of valid data, also an LED connected to Pin 17 indicates the arrival of data. The data pins from the decoder are connected to the port 3 pins of the microcontroller. It is a Vega kit make model type [19]. It requires a resistor of 27 K Ohms between pin15 and 16 to get the clock for transmission. A bypass capacitor of 0.1 microfarad is connected between VCC and GND to bypass any high frequency interference. The data pins 10 to 13 with the enable pin 14 are connected to the port 3 pins of the microcontroller.

3.8 Sensors (Temperature, voltage, Current)

There are three Parameters to be acquired for processing. The parameters are Temperature, voltage and Current. These data are gathered and transmitted to the supervisory system regularly. All these parameters are from respective sensors. As microcontroller can be interfaced with a logic level signal, the analog voltages sensed from the sensors have to be converted to the digital form.

3.8.1 Temperature

The temperature sensing is done through a temperature sensor LM35 [6]. It is a three terminal device in TO92 casing (pin 1 for VCC, Pin2 is output and Pin 3 is GND). It gives 10 mv per degree Centigrade as output. The output from the LM35 sensor is connected to the Pin 2 of an Analogue to digital converter, type MCP3202 [12]. ADC
MCP3202 is an 8 pin IC, working at +5 VDC. The microcontroller takes the digital data serially from the ADC and convert it a suitable decimal value and displays on the LCD.

3.8.2 Voltage
The voltage as a parameter is measured and digitized for processing. We have connected a 5 K Ohms potentiometer across 5 VDC. The center terminal of the potentiometer is connected to the Pin 2 of an ADC, MCP3202. It is a 12 bit serial ADC. The pins from ADC are connected to the pins 36, 37, 38 and 39 of the Microcontroller respectively. We can vary the input analogue voltage to the ADC by varying the potentiometer.

3.8.3 Current
We have connected a variable potentiometer (5k Ohms) in series with a resistor of about 100 Ohms and connected across the power supply Of 5 VDC. Hence when the potentiometer is varied, the current in the circuit varies. Then a proportionate voltage is available across the resistor 100 Ohms. This sample is taken and digitized using an ADC, MCP3202. This ADC pins are connected to the microcontroller pins 6, 7, 8 and 28.

4. Software implementation
Visual basic [1] is a high level programming language developed from the earlier DOS version called BASIC. Although Visual Basic .NET has the main stage in current IT field, Visual basic hasn't lost its powerful status among the programmers.
Visual Basic is an event-driven programming language. This is called because programming is done in a graphical environment unlike the previous version BASIC where programming is done in a text only environment and executed sequentially in order to control the user interface. Visual Basic enables the user to design the user interface quickly by drawing and arranging the user elements.
A VB program is developed for the database to collect data. The control action can be initiated by clicking on the PC screen buttons.
All other programs are written in assembly language.
The Computer with a database stores the received data (Temperature, Voltage, and Current) regularly as and when received. The Microcontroller has only one port with RXD and TXD for serial link. But we need two, one for serial link directly between Data acquisition unit and the PC. When the enable pin 1 is enabled, the Microcontroller will have serial communication link with the PC. The switching action is taken care by the Software Program, no human intervention required. Whenever a Microcontroller is to be serially linked with a PC (RS232 link), then a converter IC like Max232 is required for logic voltage level changing.

4.1 Flow charts
The flowcharts depicting the monitoring unit and the data acquisition are shown in Figure.4 and Figure.5.

4.1.1 Monitoring unit

![Flow chart for monitoring unit](image-url)

Fig. 4 Flow chart for monitoring unit
4.1.2 Data acquisition unit

1. **START**
2. **initialize special function registers by name**
3. **initialize hardware signals by name**
4. **initialize temporary data location by name**
5. **initialize flag registers and data**
6. **initialize LCD and display power on**
7. **is switch in serial or RF**
8. **wait for data from mon station**
9. **is RF data packet received flag**
10. **store received data for display**
11. **validate received data**
12. **jump loop back**

**A**

**IS DATA = 'S'**
1. **set B flag**
2. **is flag 1 or 0**
3. **scan the parameters temp, voltage & current**
4. **read temp ADC**
5. **store temp value and display on LCD**
6. **read ADC voltage value, store it and display on LCD**
7. **read ADC current value and display on LCD**
8. **make temperature packet and send to monitoring unit**
9. **make voltage packet and send to monitoring unit**
10. **make current packet and send to monitoring unit**
11. **jump loop back**

**A**

**IS DAT \[= @ \]**
1. **relay on**
2. **relay off**

**IS DAT \[= @ \]**
1. **relay on**
5. Results and discussion

The parameter display form is as shown in figure 6. It has been developed by VB software. It displays some of the parameters like temperature, voltage and current along with the date.

Now the maximum temperature is set as 30°C, the parameters are changed and observed that even in Monitoring unit and RTU is updated. The observed parameters on application window are Voltage as 3.84V, Current as 51.1mA, Temperature as 30°C. During this period the relay was found switched ON as temperature has crossed the limit. As soon as the temperature gets lower than limit relay gets switched OFF. The parameters changed are stored and displayed in separate box. It is represented in Figure 8.

5. Conclusion

Today’s world is fast growing; people need any system to be fully automated. It has made system sophisticated and easy to use. It has helped to reduce human errors as it
reduces the human interface to certain level. The highlight of this project is it has got two communication lines one as redundancy where in can be used in case of failure. It also monitors all the parameters and it controls at the same time. As we have database for system there is no need to maintain log book and it makes things error free and easy to access. This is an important tool in the control system. It has got wide range of applications of its own.

At present we are implementing the application of this project only to three parameters namely Voltage, Current, Temperature. As still more parameters like Power factor, Phase graphs can be implicated under this. By using servers we can connect many numbers of RTU units and have data monitoring and controlling at a time. We have used basically RF and Serial communication so in future it can de enhanced to GSM, Satellite and optical fiber communication providing large range. We can add security tool to it in order to make it still more advanced and effective

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