Using SCADA & Microcontroller for Monitoring and Automation of Petroleum Station Tanks

Carlo Makdisie*, Badia Haidar**

*Power Department, Mechanical &Electrical Faculty- Tishreen University, Lattakia, SYRIA makdisiecarlo@yahoo.com

**Structural Department, Civil Engineering Faculty- Tishreen University, Lattakia, SYRIA haidar.b@gmail.com

Abstract— Most of industrial production lines need an accurate control, especially in the case of very sensitive production materials. Microcontroller will be used to control the essential parameters such as: Temperature, pressure, fluid flow, humidity, and the liquid level….etc. of the storing tanks of petroleum stations. We will represent the mentioned system by aid of modern programs (Labview, Protues, PIC C Compiler) to achieve a high accurate control of the required parameters, in addition to using SCADA for supervising and controlling all the system to avoid any unexpected faults; like fire catastrophe and making the system work with high accuracy. In order to automate an oil refinery and minimize human intervention, there is a need to develop a SCADA system that monitors the plant and helps to reduce the human errors.

Keywords – Automation, Labview, Protues, Microcontroller (MUC or µC), Port, SCADA, RS232.

I. INTRODUCTION

A lot of industrial production systems need a supervising and control system (SCADA) [1]. In (SCADA) , the data will be sent to a master (main) computer which receives the sensors outputs for processing them and sends control pulses to the actuators of the studied system to control the required parameters (controlled parameters) [2], such as temperature, pressure, humidity, fluid flow, and the liquid level inside the tanks as shown in Fig.1.

1.1. The importance of SCADA system

In order to automate an oil refinery and minimize human intervention, there is a need to develop a SCADA system that monitors the plant and helps to reduce the errors caused by humans. [3]

Fig.1. Diagram of tank gauging with computers system SCADA

Supervisory control and data acquisition – SCADA refers to ICS (industrial control systems) [4&5&6] used to control infrastructure processes (water treatment, wastewater treatment, gas pipelines, wind farms, oil tanks stations, etc), facility-based processes (airports, space stations, ships …etc,) or industrial processes (production, manufacturing, refining, power generation …etc). [3&7]

The following subsystems are usually present in SCADA systems: [8]

• The apparatus used by a human operator; all the processed data are presented to the operator

• A supervisory system that gathers all the required data about the process

• Remote Terminal Units (RTUs) connected to the sensors of the process, which help to convert the sensor signals to the digital

  data and send the data to supervisory stream.

• Programmable Logic Controllers (PLCs) used as field devices

• Communication infrastructure connects the Remote Terminal Units to the supervisory system.

1.2. *Operation Principle of the compact system including peripherals devices*

Nowadays fuel stations are operated manually. These fuel pumps are time consuming, require more manpower [9] and do not provide the accurate fuel amount for both customers and dealers. Flow sensors were used to measure the fuel amount in these fuel stations. In [10] they operates a remote monitoring system for pump output monitoring in distributed fuel stations in Nigeria by recreating a fuel dispenser with an Atmel 89C52 microcontroller based system which has an added feature of being able to send collated data via its serial port to a web-enabled PC to enable access to this data from anywhere in the world using a web-enabled device [10]. The error in oil dispensing to the tank may vary from person to person and sometimes it depends on method of measuring also. Hence it is required to have oil dispensing units which will be able to function irrespective of time, place and person [11].

The controller will compensate the fuel volume depending on the temperature changes. PIC16F877A is used as a controller for this purpose. LM35DZ will sense the environmental temperature and then it will send an analogue signal to the controller as input signal. Depending on the input signals [12], the controller will control the total fuel pumping time with compensation time. The fuel level in the tank is monitored by the level sensor. The metal probes are used in this control as fuel level sensors. The block diagram of the system is shown as in fig.2.
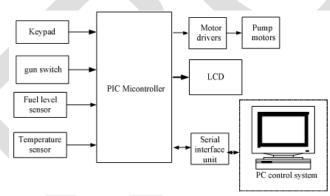

Fig.2: Block Diagram of the system

1.3. *PIN configuration and description of PIC16F877A*

The PIC microcontroller PIC16f877A is one of the most renowned microcontrollers in the industry. This controller is very convenient to use. The coding or programming of this controller is also easier. One of the main advantages is that it can be write-erased as many times as possible because it uses FLASH memory technology. It has a total number of 40 pins and there are 33 pins for input and output (fig. 8). PIC16F877A is used in many pic microcontroller projects. [13]
PIC16f877A finds its applications in a huge number of devices. It is used in remote sensors, security and safety devices, home automation and in many industrial instruments. An EEPROM is also featured in it which makes it possible to store some of the information permanently like transmitter codes and receiver frequencies and some other related data. The cost of this controller is low and its handling is also easy. It is flexible and can be used in areas where microcontrollers have never been used before as in coprocessor applications and timer functions etc. [13]
The goal of our paper is to study the use of SCADA to demonstrate petroleum storing stations, which consists of many tanks and controlled by microcontroller-PIC.

II. IMPORTANCE AND GOALS

Our study contains many stages:

2.1. The design of hardware

This stage includes the design and production of instruments that receive, assemble, and process the data of controlled parameters. As a result, the mentioned instruments will send the control pulses to actuators for controlling the required parameters at determined values. [1&14]

2.2. The design of software

This stage treats the received data and represents them graphically and numerically, then exports and releases related reports which contain the details of technology process and the resultant events record. In addition to sending alarm signals in case of a failure event.

2.3. The simulation of studied system

In this stage we use the suitable programs to simulate: each part of the studied system, all used sensors, and the related measurement instruments such as Protues, Labview.

a) Labview allows us to represent the used storing system with all essential parts to confirm the accuracy of the industrial technology process.
b) Special programs of µC: PIC(C) Compiler for programming the (PIC 16F877A).

2.4. The communication system and the protocol

This stage provides the data transferring between the computer input and output i.e. allows the data transferring between sensors and computers and vice versa and provides the communication between computer and actuators for a long distance up to a few kilometres. The mentioned communication system also allows using the satellite and internet with ability to encode the transferred data to confirm the system protection and maintain the accurate secrecy (as in nuclear reactors, heavy water treatment stations, and military submarines).

III. SEARCHING METHOD

Any control loop in the process control industry works in the same way, requiring three tasks to occur:

_ Measurement

_ Comparison

_ Adjustment

In Figure 3, a level transmitter (LT) measures the level in the tank and transmits a signal associated with the level reading to a controller (LIC). The controller compares the reading to a predetermined value, in this case, the maximum tank level established by the plant operator, and finds that the values are equal. The controller then sends a signal to the device that can bring the tank level back to a lower level—a valve at the bottom of the tank. The valve opens to let some liquid out of the tank.

Many different instruments and devices may or may not be used in control loops (e.g., transmitters, sensors, controllers, valves, pumps), but the three tasks of measurement, comparison, and adjustment are always present. [15]

3.1. Suggested method for controlling and monitoring

Using PLC gives us many advantages compared to the microcontrollers due to: the easy programming of PLC, the ability of the PLC system to protect the studied system from interference, the high stability, the high efficiency, and the low cost of the controlled system (automated). [16]
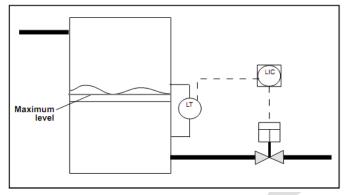
Fig.3. A simple control Loop

The suggested idea in this paper is to use the microcontroller (PIC16F877A or other MUC) connected to Labview program for building a highly accurate supervising and control system (SCADA) for storing petroleum integrated station at low cost due to the previously mentioned features of PIC16F877A.

The studied system consists of (8) analogue sensors, (7) digital sensors, supervision display screen (SDS), and LCD connected to (PIC) such as; all elements mentioned above.

Regarding to the distance, the communication lines between (SDS) and (PIC) could be via protocol (RS232) or (USB) or (TCP /IP); especially when communication is via internet or satellite. [14&17]

3.2. The search method includes

1- The design and the simulation of PIC circuit .In addition, writing the (PIC) program by using the special code (PIC C Compiler) and building the communication protocol for (sending/receiving) data in accurate form.
2- The design of the controlled studied system by using Labview, which shows the bi-directional internal data transfer in different instruments, and represents all results via counters and LED's (for presenting the analogue/ digital sensors in sequence) considering the importance of legality of the required number of switches on the (Labview) control screen, to achieve the accurate control of the output actuators of the used (PIC).

3.3. The search steps & the materials of each step including discussion and results

IV. DISCUSSION AND RESULTS

4.1. Discussion

1) The hardware design and the contents :
The design of this part needs to the following contents:

Table.01: requirements of hardware design

Microcontroller :	PIC16f877A
Compiler :	PIC C Compiler
Simulation Program :	Protues 7.8
System Interface :	Labview 2011
Communication :	Via COM Port

The microcontroller (PIC16F877A) contains 5 Ports that are used according to the following table below

Table.02: the function of microcontroller ports

PORTA	5 Analog sensors
PORTB	8 Digital Output
PORTC	RS232 Communication
PORTD	7 Digital sensors
PORTE	3 Analog sensors

The configuration of used PIC with different ports is shown in fig 4 below:

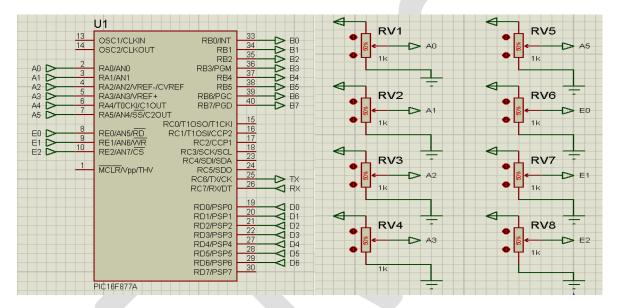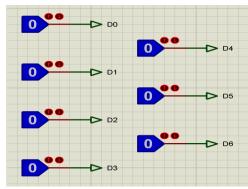When the analogue sensors are connected to the ports (A+E), it is very necessary to provide the mentioned sensors with power supply (0-5 volt) as shown in the following practical circuit (fig 5):

Fig.4: the representing of PIC using Protues   **Fig.5: Supplying of Ports A&E**

In the following figure 6, the digital sensors that are designed by using the Protues program have only two logic states (I/0).

The connected LEDs to the (port C) represent the connected devices (actuators) to the output of the microcontroller (PIC) to achieve the control of the required parameters via relays, motors, coolers or valves such as in fig 7.
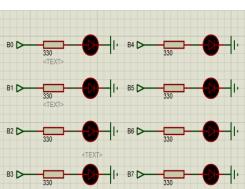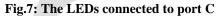
Fig.6: Design of digital sensors using PROTUES

Fig.7: The LEDs connected to port C

The assembling of all mentioned parts of the studied system for representing the final form is achieved by using the Protues program as shown in the fig 8
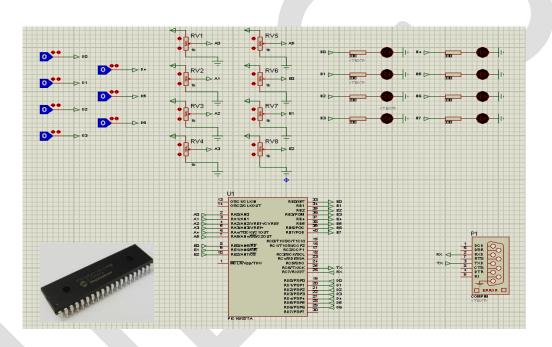

Fig.8: The general configuration of PIC by using PROTUES Program

2) Software: writing the program of PIC :

In this part, the ability of sending/receiving data between the main computer and the PIC is required. Considering the communication protocol(RS232) was used in our study where each byte of received data by the computer will contain the values 0-255, while the sending of data will be achieved by using the encoding system (ASCII).Since we can obtain the ASCII code from (PIC C) program:

PIC C compiler >> tools >> ASCII.

3) The construction of programming environments of the control system:

This aim is achieved to provide the communication for sending/receiving from Labview program to PIC and vice versa via com-port (RS232) through (NI VISA runtime engine) via many stages:

First stage: The communication will start up to determine the com-port address as shown in fig .9.
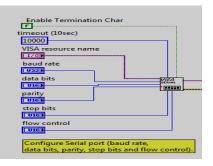
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Fig.9: The communication of PIC with Labview program via Com-Port RS232

Where the bytes are connected according to the following table.03:

Table.3: The Bits positions of serial port

Timeout	Constant
VISA resource name	Indicator
Baud rate	Constant
....	....
Flow control	Constant

Using (Constant) expression in the previous table was done to achieve removal of the displayed values from the front panel for protection purposes Fig (10-A).

Second stage: Sending the data from Labview Front panel to PIC according to the block shown in the following Fig (10-B):

Third stage: Receiving data from microcontroller (PIC) into the front panel of Labview program according to the block shown in the following [Fig 10-C].

Fourth stage: In this stage, the communication with com-port is closed (Fig 10-D).
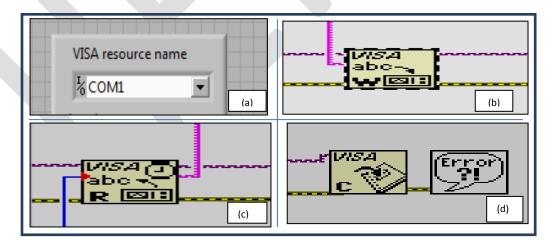

Fig.10: The interconnection between Labview front panel and PIC

4.2. Results

4.2.1 Explaining the mechanism of sent data from Labview →PIC

In this case, all analogue switches are closed in Labview program to achieve the control of required parameters connected to the port C, where the switching on of one switch (S1) in Labview program will provide output voltage (5volt).

Then this voltage can control the operating of a relay which in turn operates consequently the connected motor to demonstrate the controlled studied parameters (liquid level, temperature, pressure,…etc.)

Therefore, the sequence operation of 8 switches, and assembling the output signals and converting them into digits after regulation in (Array) contains 255 digits [0-255].

Then any digit of the previous Array will be encoded by ASCII system as shown in the following figure (11-a):

4.2.2 Explaining the process of receiving data from microcontroller (the mechanism)

The sent data from microcontroller (PIC) are regulated by using the matrix (data-send), which contains thirteen distributed values as shown in the following figure 11-b.
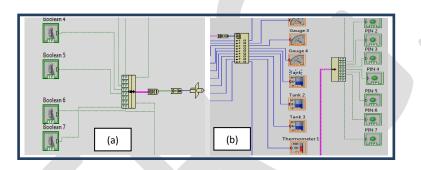

Fig.11: The process of sending/receiving data using ASCII

As a result:

In this paper we obtain many advantages; such as:

- The simplifying of the maintenance of the suggested system and high programing flexibility.
- Low cost system compared to other conventional SCADA systems. [18&19]
- The ability of Labview to add artificial intelligence, and reduce the number of humans required for management , in addition to creating periodic reports about different events in the station and required maintenance

V. CONCLUSIONS AND RECOMMENDATIONS:

- The system automation was designed by using Protues and Labview programs [Fig 12]**,** where the connection between the two programs mentioned above is very necessary to get the illustrated result shown in Fig 12.
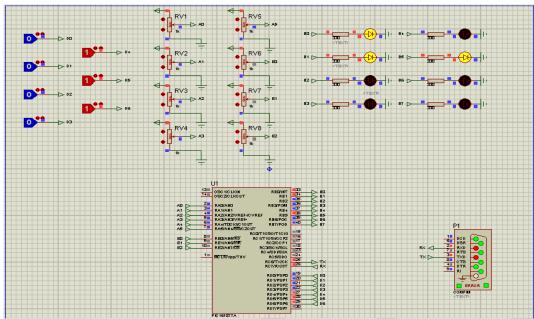
Fig.12: The system Automation by using Microcontroller represented by aid of protues and labview programs

- The clearing of data (delete) will be achieved by two stages:

At the first stage:

At the beginning the checking of the start and the end of protocol is done and compare result data with the data coming from PIC as shown in the following fig,13.
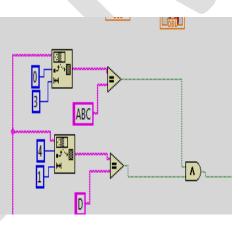

Fig.13: The check-up of protocol

At the second stage:

- Only at the end of the first stage, the access into case structure must be done to confirm the data accuracy (i.e. the similarly of the start and the end of the protocol 100%) to achieve the discharging of the data into counters in the case of analogue sensors, and into LEDs in the case of digital sensors.
- The protection of PIC from noise and interference will be achieved by using protection capacitors for discharging the interference signals, then will replace the PCB of PIC inside a suitable special bodywork (Box).
- The suggested coded program was written by compiler PIC C for use PIC16F877A. The mentioned program allows us to connect PIC to Labview program and control the required parameters.
- The suggested program given in appendix A allows controlling other parameters such as volume, cathode protection, pressure, accuracy, leakage, safety factors…etc. [14&19]
- Other tank gauging technologies could be used instead of (gradual strip + float) [Fig. 14-a] such as : manual ,(servo + float) ,radar , hybrid . [14]
- The possibility of replacing suitable safety equipment on the tanks to achieve the data transferring is illustrated in Fig. 14-b.
- We can use the same technology and programs for automation of desalination water stations. [20]
- The use of GUI will add accurate performance of the control system when using microcontroller with LM35DZ. fig. 15. [3]
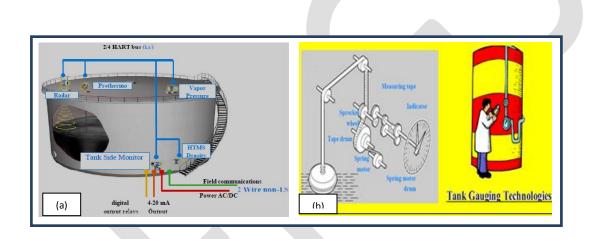

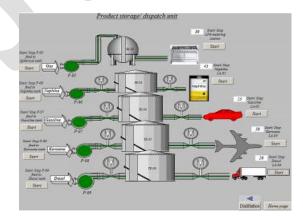**Fig.14: The measurement technology used in petroleum tank**

Fig.15: The produce storage/the dispatch unit GUI in the run mode

VI. APPENDIX (A): PIC Program

The microcontroller code:

```
#include <16f877a.h>
#device adc=8
#use delay(clock=4000000)
#use rs232(baud=9600,xmit=pin_c6,rcv=pin_c7)
#fuses xt,nowdt,noprotect
#byte porta=5
#byte portb=6
#byte portc=7
#byte portd=8
#byte porte=9
int x;
void ioset(){
set_tris_a(0xff);
set_tris_b(0x00);PORTB=0;
set_tris_d(0xff);
set_tris_e(0xff);
setup_adc(adc_clock_INTERNAL);
setup_adc_ports(ALL_ANALOG);
}
void main(){
int a,b,c,d,e,f,g;
int sum;
int y,z,i,j,k,l,m,n;
ioset();
y=z=i=j=k=l=m=n=0;
 while(1){
  x=getc();
portb=x;
set_adc_channel(0); delay_us(1000); y=read_adc();
y=y*5/255;
set_adc_channel(1); delay_us(1000); z=read_adc();
z=z*5/255;
set_adc_channel(2); delay_us(1000); i=read_adc();
i=i*5/255;
set_adc_channel(3); delay_us(1000); j=read_adc();
j=j*5/255;
set_adc_channel(4); delay_us(1000); k=read_adc();
k=k*5/255;
set_adc_channel(5); delay_us(1000); l=read_adc();
l=l*5/255;
set_adc_channel(6); delay_us(1000); m=read_adc();
m=m*5/255;
set_adc_channel(7); delay_us(1000); n=read_adc();
     n=n*5/255;
      a=b=c=d=e=f=g=0;
   if(bit_test(portd,0)==1)a=1;
   if(bit_test(portd,1)==1)b=2;
   if(bit_test(portd,2)==1)c=4;
   if(bit_test(portd,3)==1)d=8;
   if(bit_test(portd,4)==1)e=16;
   if(bit_test(portd,5)==1)f=32;
   if(bit_test(portd,6)==1)g=64;
sum=a+b+c+d+e+f+g;
if(sum==0)sum=128;
putc('A');
putc('B');
putc('C');
putc(y);
putc(z);
putc(i);
putc(j);
putc(k);
putc(l);
putc(m);
putc(n);
putc(sum);
putc('D');
delay_us(990);
}}
```

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