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Intelligent electronic control in reading water meters

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Abstract
The main function of the smart meter system is to transport the volume consumption value to main data base unit (server or main computer) through some repeating points. The system included these elements: The flow sensor, the valve (DC solenoid valve), the transceiver, the controller, the LCD, Vent valve Each home or factory connected to smart meter and these meters relay the data to sub stations through any appropriate method these methods could be : Wired method Cables. RF communication methods (AM and FM), GSM network Wi-Fi connection, Ethernet network. Then the substation carries the data to main station, and the master computer does bill processing while no manipulation attempt, the substation will read the consumption and then convert it to m3. Also the authority can easily control the service so they could cut the service out by sending the stopping code to the meter**.** The benefits of smart metering for the utility accurate meter reading, no more estimates, improved billing, accurate profile, true costs applied and Improved security efficient procedure. We have achieved the goal of research; It can be used efficiently in Lima Company.
Kay word: smart, water meters, sensors, controllers, bill value.

1- Introduction

After the privatization of water authority in Jordan, Lema Company took over this task. As a result of that an improvement in administration affairs took place. But very important activity of the company, which is the billing system, is still untackled. Up to date traditional water consumption meters count the volume of consumption. In order to determine the cost of water consumption meter reader (employer) should visit the property periodically and take the reading. After that the reading is entered into the billing system and the bill is produced. For a big city like Amman, the above mentioned procedure seems to be difficult, costly and inflexible. Such a process is always associated with numerous problems. Many meters are installed in locations that require the utility to schedule an appointment with the home owner in order to get access to the meter. In many areas customers demand that their monthly water bill be based on an actual reading instead of an estimated monthly usage based on just one actual meter reading made every (12) months. Moreover, many families nowadays both husband and wife are workers and not available at home during working day. This creates difficulties for organizing appointments with meter reader.

At the time being water consumption cost is calculated according to the following formula:

Bill value = C + V x (WP + SP) + f

Where: C: constant value equal to (1), wp : water price JD/m^3, which depends on water Consumption range

V : water consumption (m^3) sp: sewerage price , which also depends on

F=1.91 Water consumption range

An example, for a consumption range between (13-18) m^3, sp=0.25 JD and wp=0.5JD, while for the consumption range (31-42) m^3sp= 0.7JD and wp= 1.4JD. For the first range if the consumed volume is 15m^3 , the bill value is equal to : 1 + 15(0.25 + 0.5) + 1.91 = 14.16 JD.

If the owner is at a vocation and there is no possibility for issuing a bill for the given month, and the bill is issued at the end of the next month, where the consumption has come up to 32 m^3, the bill value will be equal to 71.11 JD. This is really a serious problem that must be addressed.

Considering the above mentioned problems, one can easily conclude that such an old fashion billing system must be replaced by an automatic system with the required hardware and software components. Thus the target of this work is to design a simple prototype of a smart

General description of smart billing system

The main function of the intelligent meter system is to transmit the consumption volume value to a main database unit (server or main computer). Each consumer facility is connected with a smart meter which relays data to a substation through an appropriate technology such as Wi-Fi connection, Ethernet network, DSM network or fixed telephone lines. The substation can transmit data to a main station through internet network and

there the master computer performs billing processing and database updating. After that the user can check his bill through internet network. The consumer shall be able to pay his bill through internet, mobile telephone or by traditional way. At the same time authority can easily control the service for each subscriber individually. For example in case of receiving a thieving message it can cut the service by sending a stooping code to the meter.

2- Components of Intelligent consumption meter system

The main components are the following:

- Smart flow meter with a pulse output (B-meter, model GMB-RP-R). The meter is a multi jet water meter, wet dial with protected rolls. It is equipped with a pulse output emitter (reed contact). Voltage range is 0.02-24 VDC. Maximum interrupted current is 0.5Aand the maximum power is 10 W. Smart meter is usually an electrical output meter that records consumption during a time interval and communicates that information to the utility for monitoring and billing purposes. Smart meters enable two-way communication between the meter and the central system. Unlike traditional consumption meters they involve near real-time sensors. Smart sensors are believed to be less costly alternative to traditional interval or time-of-use meters. The selected smart meter is shown in figure no (1).

Figure N0 (1)

2-1- Dc Solenoid valve.

It is used to control water flow through the meter. The size is 0.5" and the operating pressure in range (0 – 9.8) bar. The power is 2 W and the power supply is 24VDV.

The connection of the solenoid valve, meter and control circuit is shown in fig. 2,3

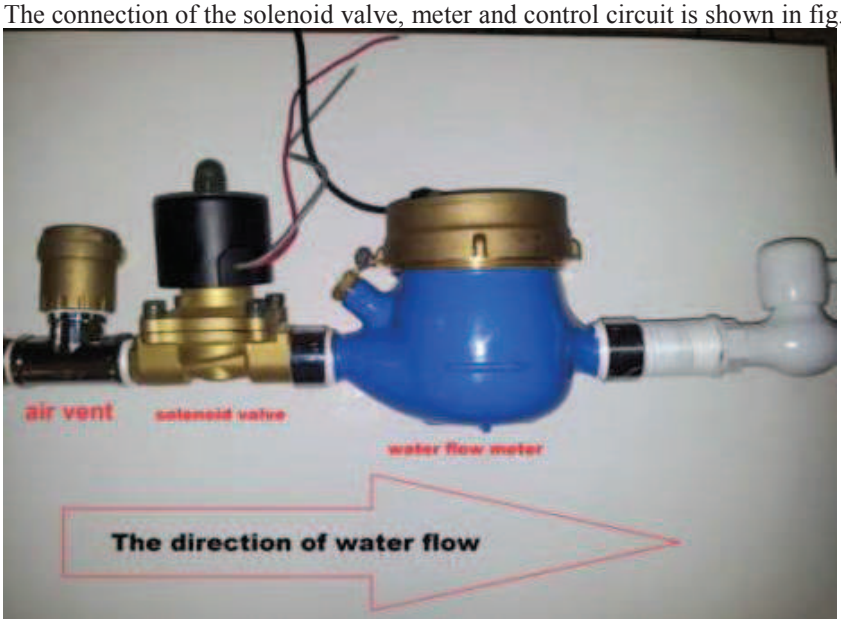

Fig (2) systems element

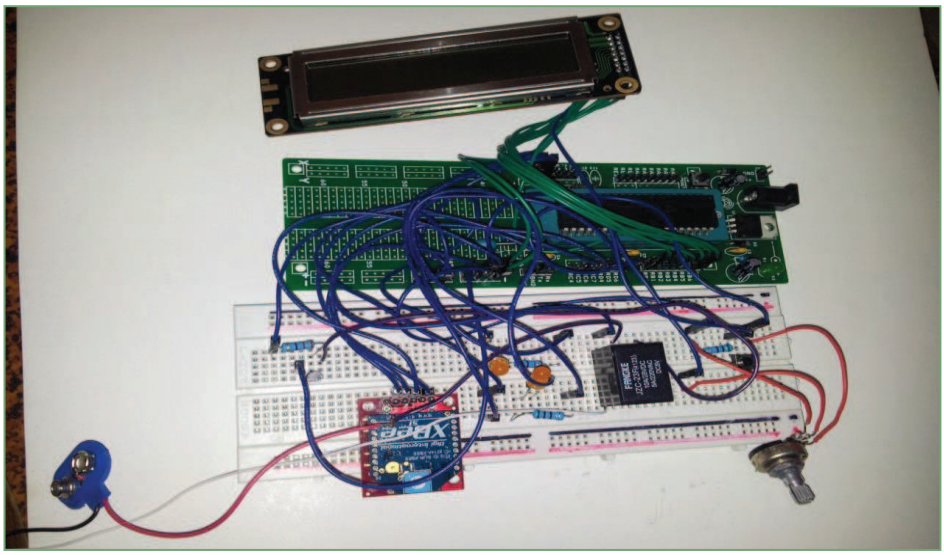

Fig (3) control circuit diagram

- The transceiver. We selected XBee transceiver to transmit and receive the readings and orders. ZigBee is normally used when it is required to enable reliable , cost effective , low power wirelessly networked monitoring and control based on an open global standard. Important to note that the ZigBee alliance encompasses the IEEE802.15.4 standard, which specifies the communication architecture that is appropriate for
- The controller. The micro controller PIV16F877A is selected to collect the meter reading and to send it to the substation, and to receive orders to open or shut down the service.
- The interface between the user and the meter system.

A 2X16 LCD is used as a simple indicator and shows the system reading and state messages also.

- Vent Valve. This valve is used to remove air from pipe line carrying liquid. Having a purge element, this valve automatically vents air accumulated in the plumbing in water closed circuits, thus improving circulation of water.

Connection diagram between different components of the system is given in figure NO (4)

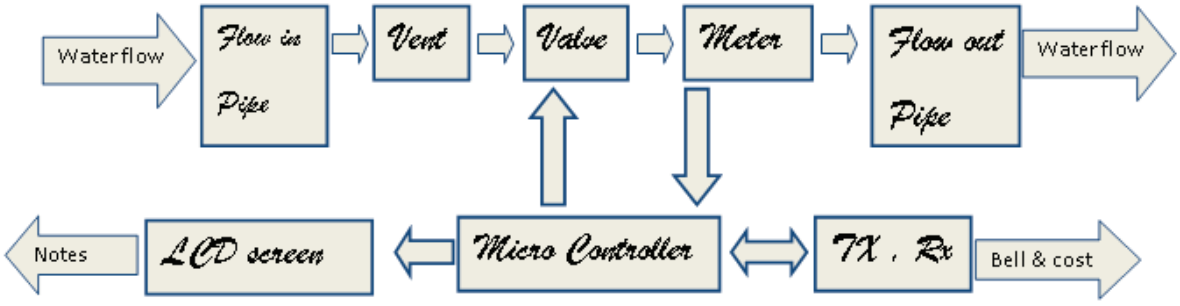

Figure NO (4-a) smart meter parts connections

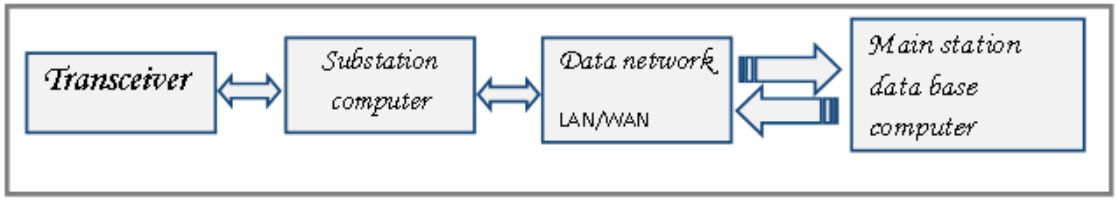

Fig (4) substation – main station parts connections

2-2- System working modes

- The first mode is the normal mode. In this case there is no data ready to be sent to the station and there is no thieving action. The solenoid valve is open and the meter is counting and compiling consumption. Consumption value is saved in the PIC, and the LCD displays consumption value and shows that the valve is ON.
- The second mode is the mode of sending data. This mode is similar to the normal mode with the exception that sending and receiving the amount of consumption takes place.
- The third mode is the thieving event mode. If a trial to steal the meter takes place an electrical switch opens and as a result of that a message appears on the LCD screen, unit title and theft code is sent to the company repeatedly until the company responds. The controller will hang and stop responding until a reset code is sent from the company to the system.
- The forth mode is the automatic opening and closure of the solenoid valve. In case of a delay in paying bills during a cretin period the service is stopped automatically by sending a specific code to the station and then to the meter.
- After paying the bill the valve is reopened by sending another code to the station.

2-3- Control sequences of the meter and the station

Flow chart NO (1) shows the control sequence of the meter and flow chart NO (2) Shows the control sequence of the station.

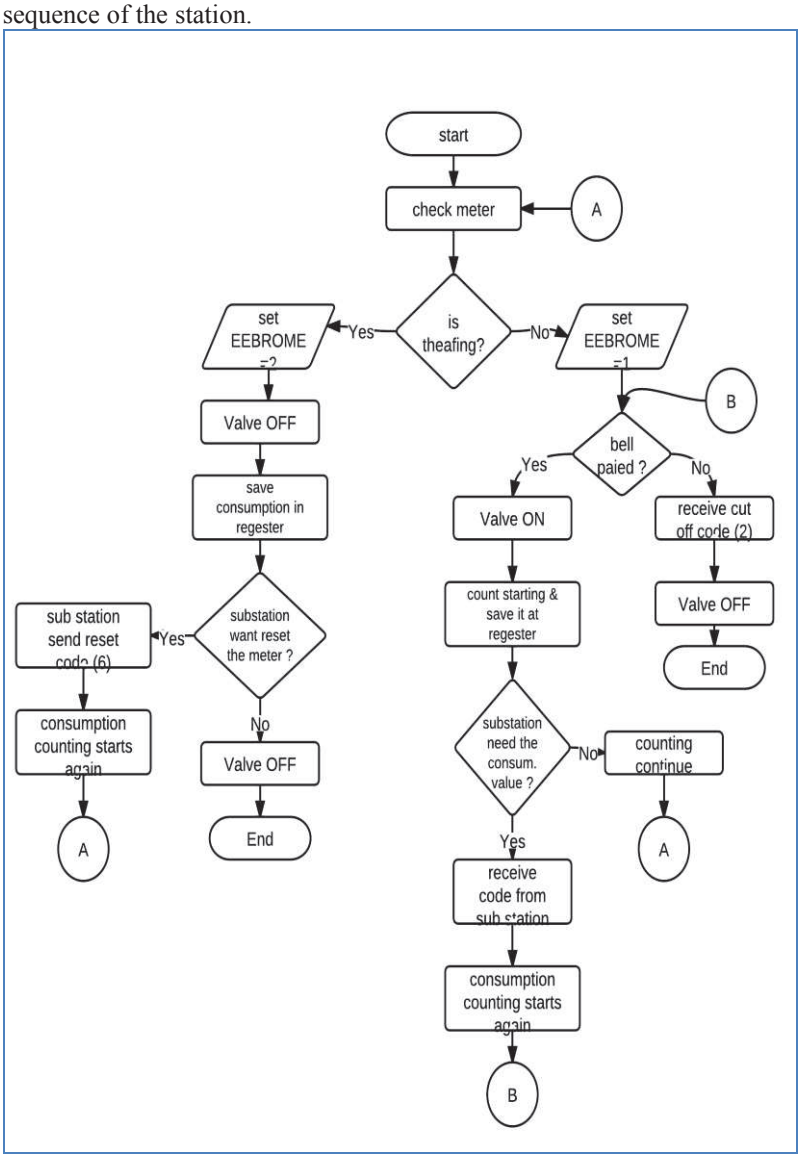

Figure NO (5) – Flow chart NO (1)

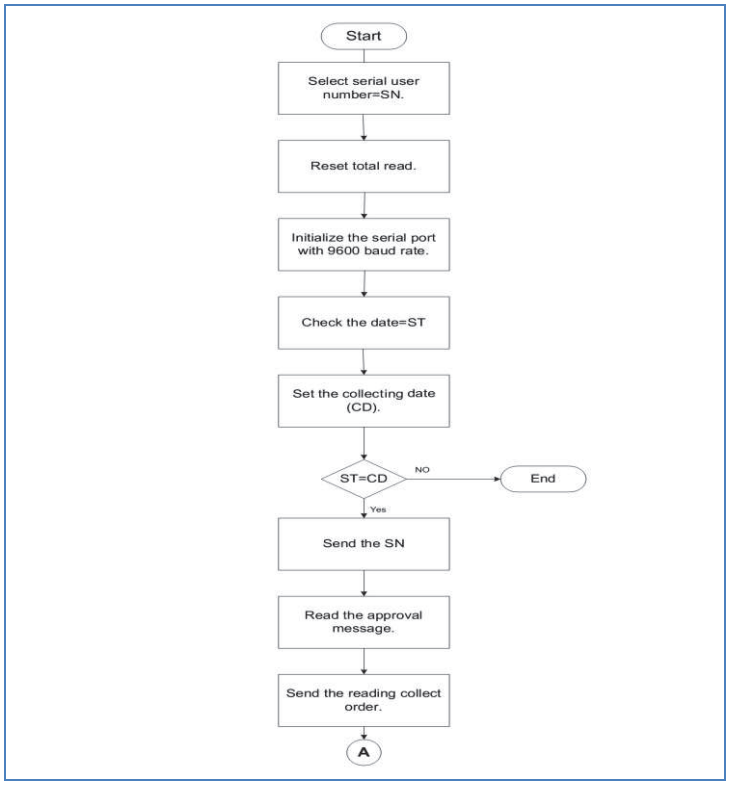

Figure NO (5)- Flow chart NO (2)

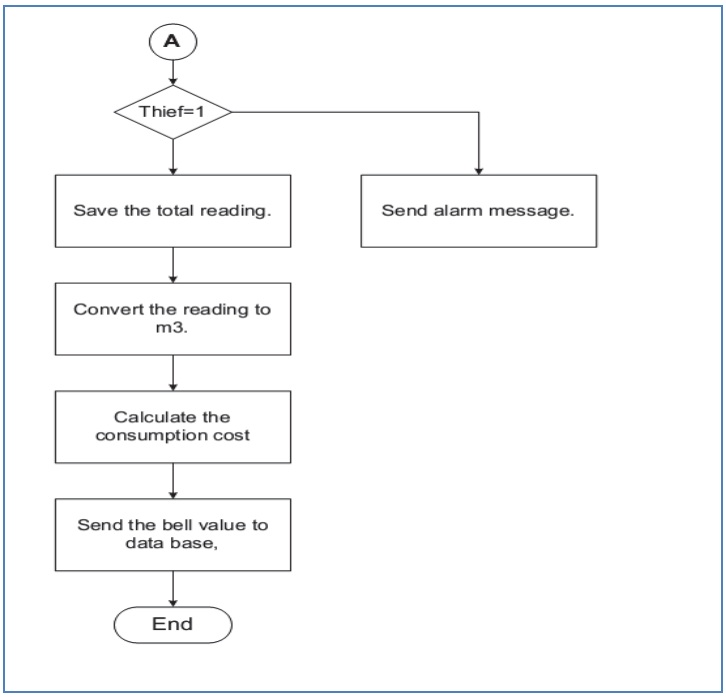

Figure NO (5)- Flow chart NO (3)

The PIC program which realizes flow charts is given at the end of the pape). In the first loop in the PIC program the consumed number of litters is counted by the counter which is connected to PORd.7 , and then it is provided to the LCD.In the first loop two registers(X,T) are used. This is because after sending the consumed value through the substation , the value of (X) will be reset, so this value is saved in register (T).The second loop

serves to send and receive data. The USART port is set for working with 9600 baud rate. After checking the security switch state , if there is no manipulations attempt, the controller reads the consumption.If a manipulation attempt exists , the thieving message is sent to substation for water cut-off and a message is shown at the LCD screen.If the meter receives order to cut-off service PORTd.3 is de-energized.If the meter receives the user serial number it will respond with acknowledge to the substation and wait sending reading order.. When the last is received , the meter sends the reading to the substation.
All user serial numbers are defined on an array. The computer transmits the serial number and all other meters in the network receivethe order. The meter with specified serial number will respond by sending acknowledge to the substation. Nextthe collecting order is sent. If the acknowledge message is not received the meter will send it again, the thieving action is tested , thieving message will show up and is sent to the database if a trial to open the meter box occurs.If there is no manipolation attempt, the substation will read the consumption , converts it to (m^3), calculate bill .

3- Program test

```
program TEST1          ' program name

SYMBOL COUNTERIN=PORTd.7   ' consumption input for counter
SYMBOL THEIF=PORTD.1     ' theifing input port
SYMBOL valvee=portd.4    ' valve output port
CONST VALVEON as BYTE =1  'constant for xbee to make the valve on
CONST VALVEOFF as BYTE =2 'constant for xbee to make the valve off
CONST EEPROMRE as BYTE =6  'constant for xbee to reset the EEPROM value
CONST SEND AS BYTE=3       'constant for xbee to send the con. for substation
CONST SN AS byte =89      'constant for xbee to send the address for substation
DIM T,X,Y AS WORD          'registers for con. pulses counting
DIM L,V AS byte        ' L= usart register, V= EEPROM register
DIM rese,e as byte      'reae= valve status reg. , e= thifing reg.
DIM M as string [5]     'string for LCD

main:
trisb=0   'PORT B as output for LCD
portb.1=1 ' LCD RS=1 cause we use it for data input
portb.2=0 'LCD w/R=0 for writting operation
portb.3=1 'LCD ENABLE=1

TRISd=%10000010 ' to indicate the port D.7.1 AS INPUT & the rest as output
X=0   ' reg. initial value
T=0   ' reg. initial value
Y=0   ' reg. initial value
V=0   ' reg. initial value
rese=0 ' reg. initial value
portd.0=0 'portd.0 for pulse indicator led and that is the initial value for it
portd.3=0 'for xbee sending instruction when thifing (led) and that is the initial value for it
portd.4=1  ' for valve and that is the initial value for valve ( valve open )
USART_Init(9600)' usart baudrate
lcd_config(portb,7,6,5,4,portb,1,2,3) ' for LCD preamble
lcd_cmd(lcd_clear) ' for clearing the LCD
lcd_cmd(lcd_cursor_off) ' to stop the cursor
' Q loop to check the counter status
Q:
V=EEPROM_Read(2) ' reading location NO. 2 from EEPROM
DELAY_ms(1000)  ' Delay for reading operation
IF V=1 THEN   'condition if the counter is ok &  no theifing happened
valvee=1   ' valve still open
rese=0      ' if no theifing it's value is zero to allow the counter to count
```



```
lcd_out(1,1,"valve on")  'print valve on (  on LCD screen )
END IF   ' loop end

IF V=2 THEN  'condition to check if the user is theifed
valvee=0    ' the valve is closed
lcd_cmd(lcd_clear) ' clear the  LCD screen
lcd_out(1,1,"valve off")  ' print valve off ( ON LCD screen )
delay_ms(3000)  ' Delay the message on LCD 3 sec.
e=0      ' to stop the xbee sending instrucion when theifing is happened
rese=1 ' to stop counting operation
END IF  ' loop end

run:
'collect data
if (COUNTERIN=1) and (rese=0) then
while COUNTERIN=1 'for debounce the counting
wend
X=X+1      'COUNT PULSEs
PORTd.0=1   'pulse indicator for one litter
DELAY_ms(100) ' delay to on
portd.0=0    ' led off
T=X   ' to view at LCD we saved the value f X at T reg.
wordtostr(T,M)  ' MUST convert T to string to view the reading at LCD
lcd_out(2,1,"consumption") ' print consumpition word at LCD screen
lcd_out(2,12,M)    ' print consumpition at LCD screen after consumpition word
end if
'sending data
if (USART_Data_Ready=1) then 'to check if the xbee ready to recive data
L=USART_Read ' reciving value from another xbee and saved the value at L REG. to indicate what i need to do
select case L 'select case to compare the L value & indicate what i need to do

case VALVEON 'to open valve case
lcd_cmd(lcd_clear) ' clear the LCD from old messeges
valvee=1  ' the valve is open
lcd_out(1,1,"valve on") ' print valve on at LCD screen
usart_write(1) 'to ensure the data reaciving by controller
rese=0  'the value is zero to allow the counter to count

case VALVEOFF 'to close the valve
lcd_cmd(lcd_clear) ' clear the LCD from old messages
valvee=0 'the valve is closed
lcd_out(1,1,"valve off") ' print valve off at LCD screen
usart_write(2)  'to ensure the data reaciving
rese=1  'the value is one to stop the counter to count

case EEPROMRE  'EEPROM reset case
usart_write(6) 'to ensure the data reaciving by controller
EEPROM_Write(2,1) 'write the value 1 at location 2 on EEPROM
DELAY_ms(1000)  ' Delay to write
V=EEPROM_Read(2)  'read the value for more check
DELAY_ms(1000)  ' Delay to read
lcd_cmd(lcd_clear) 'to clear the LCD from old messages
goto Q

CASE SEND   ' sending consumption case
Y=Y+X 'take the old & new value of pulses
```



```
USART_WRITE(Y)  ' sending the consumption
X=0 ' make the value of x zero for new count

CASE SN  ' sending serial NO. OF COUNTER case
delay_ms(10000)
usart_write(2)
case else
end select
end if

IF (THEIF=1) THEN 'THEIFING CHECKing & STOPPING LOOP
EEPROM_Write(2,2) 'WRITE at location 2 at EEPROM the value 2
delay_ms(1000)  'DELAY FOR WRITE
lcd_cmd(lcd_clear) ' CLEAR THE OLD MESSAGES AT LCD
lcd_out(1,1,"theifing") ' PRINT THEIFING MESSAGE AT LCD SCREED

lcd_out(2,1,"meter lock") 'PRINT METER LOCK MESSAGE AT LCD SCREED
rese=1 'TO STOP COUNTING OPERATION
valvee=0 ' To more ensure that valve is closed
e=1 'for xbee sending thifing instruction
END IF
if e=1 then 'send to substation thifing instruction
usart_write(5) 'NO. 5 to indicate the thifing operation
delay_ms(8000) 'delay between two instruction cause the xbee is continuous sending
portd.3=1   'LED OUPUT to indicate  xbee sending operation
delay_ms(500) ' Delay for on
portd.3=0     ' off the led

if (USART_Data_Ready=1) then  ' check if usart ready to reciving data
L=USART_Read  ' reciving value from another xbee to indicate what i need to do
select case L 'select case to compare the L value & indicate what i need to do
case VALVEOFF 'when the substation see the thifing message it's send to stop
            'xbee sending instruction and print valve off message at LCD
delay_ms(9000)
usart_write(89)
lcd_cmd(lcd_clear)
valvee=0
lcd_out(1,1,"valve off")
GOTO Q
case else
end select
end if
end if

goto run ' program end

end.
```

Conclusions

-A physical prototype model for a smart consumptionmeter system was designed and practically tested. Testing results show that the system works perfectly in accordance with the designed program.The done work may be considered as a core model for a larger network which may be built at Lima company.

-B Implementation of the designed prototype will improve the consumption management, the performance of the billing system, and the security tamper detection of equipmentand decrease the number of employes,

Future works

The GSM (Global System for Mobile Communications) networks are now available everywhere in the cities and non new infrastructure required. Thus, change the Xpee to GSM module will give the meter safer and more reliable communication way. Where the readings and orders could be sent then via SMS. This medium is really accurate and could help in database management

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