Complex Application for Protections, Control and Metering Circuits for 20 kV Over Head Line Feeder, Using a Development Microsystem with PIC 18F8722 Microcontroller

Ph. D. candidate Cirdei Cornel Dinu

Faculty of Electrotechnics, Bd. Profesor Dimitrie Mangeron, nr. 51-53, 700050, Iasi, Romania,
Tel: (+40)-232-278683, Fax: (+40)-232-237627, E-mail: decanat@ee.tuiasi.ro

*Abstract-*The Application for Protection, Control and Meterring Circuits using a Development Microsystem, simulates protection, alarms, control and metering instruments, for 20 kV Over Head Line Feeder, focusing on detecting disturbing influence of the producers, suppliers and consumers, in order to respect Power Network quality standards.

I. Description of protections and control simulations

A. Introduction

This application is divided into three sections: protection, control and power quality analyzer of 20 kV HV Over Head Line feeder, using microBasic language. One of the most important condition for Electrical Network operation is the safety function, which requires a continuity in consumers' supplying. Continuous operation of electrical installations has special importance not only because the followings of disturbances can be very serious, but also for the reason that Electrical Network, is more exposed to the failures, comparing with other systems. The severity of electrical disturbances become from the reason that a failure which appears in one side of the network, can affect entire system an can induce big damages, not only for the distribution system, but also for producers and consumers. The most principal role, of protection and control automatisations used in Electrical Network, is to limit the effects of failures and to assure continuity in consumers' supplying. In this moment are two general directions of protections and control' automatisation development of High Voltage Substations equipments using coordinated or integrated systems. The present application makes a combination between those two, because integrates all functions at the feeder level, trying to combine the safety in operations of coordinated system with the speed of integrated one, and also, comes to replace classical relays, which are traditionally used in High Voltage Substations for protections and control circuits. The second function of this application, is to command and supervise local and remote operations of Bus Bar Switches, Circuit Breaker and Earthing Switch, presented in figure 1, assuring the safety operation of each one, because of the interloks which are introduces for each specifical operation. Finally, the third function, is to analyse power quality indicators, as an digital measurement device, and being able to present selected details into four screens which are shown on the graphical display. The original contribution of this one is to count voltage, current and voltage fluctuations, out of Power Quality rules and to send alarm to the Substation Control Room.

B. Coordinating systems of alarm and protections

Aplication described below, uses a BigPic4, development System for Microchip PIC 18F8722 microcontroller. As we can see in figure.1, the development System containes following most significant devices: 80-pin, 18F8722 PIC microcontroller; an LM7805 voltage regulator for external AC or DC supply between 8V and 16V; On-Board USB 2.0 programmer; a mikroICD for Real-Time debugging on hardware level; 46 Light Emitting diodes placed in the left side of the bord, permiting to ceck level signals on the port pins; 46 Pushbutton switches to provide digital imputs to mocrocontroller's ports; a graphic LCD for displaying drawing and bitmaps, with screen resolution of 128x64 pixels; a standard character LCD, with 2 lines of alphanumeric characters; two RS-232 communication devices; PS/2 connector; seven ports with 10-pin connector providing Vcc and Gnd together with up to eight port pins for each one. Also, we use for 20 kV Over Head Line Feeder simulation, an auxiliary board, as is presented in figure.2, which have the following components:

1. Bus Bar 1/2 of 20 kV (BB1/2);
2. Bus Bar 1/2 Isolating Switch (SB1/2);
3. Circuit Breaker (CB);
4. Earthing Switch (ES);
5. Voltage/Current Transformer (VT, CT);
6. Automatic Tripping at Low Voltage Level with two steps (ATLVL);
7. Over Current Protection with two steps (OCP);
8. Automatic Re-close Equipment with two steps (ARE).
9. 4 switches which simulate Circuit Breaker, Isolating and Earthing Switches local command keys;
10. Green and red LEDs, for presenting the states of Circuit Breaker and Switches.
11. 2 potentiometers which simulate the voltage and current fluctuations.

This part of application provides simulation of following Over Head Line Feeder protections:
Over Current protection with two components:
1. Fast Over Current Feeder protection;
2. Time delayed Over Current protection;
3. Automatic Re-close Equipment with two steps (ARE);
4. Automatic Tripping at Low Voltage Level with two steps (ATLVL).

All these protections have their own alarm informations, provided into the standard Ascii LCD described before. For simulating of Over Current Protection, we use one analogical imput colected at pin RA0. This signal, comes from a 10 kΩ potentiometer (supplied from the board Vcc), and can be changed in the range of 0V to 5V. For checking the protection function, we have to close Circuit Breaker and the specified LED will show the green color. By rapid increasing of voltage range, we are able to simulate work of "Fast Over Current Feeder protection". The LED color will become red, and on the Ascii LCD will be shown indication: "worked Fast Over Current Feeder protection". At this moment will start "Automatic Re-close Equipment" and LED color will become green, together with Ascii LCD indication: "worked Automatic Re-close Equipment, step I". If failure will maintain, the overcurrent protection will work again, and also the Automatic Re-close Equipment protection, being shown on the display: "worked Automatic Re-close Equipment, step II". If still, protection is in function, Circuit Breaker, will trip for the third time and LED indication will remain red, together with LCD indication: "worked Fast Over Current Feeder protection", whithout any more equipment re-close. The same operations are available for Time delayed Over Current protection, with mention that this one, works at delayed lower current. For example, if we increase voltage range at 3V level, Time delayed Over Current protection will work after specified time, followed by the same operations described at the Fast Over Current Feeder protection. If we decrease voltage value before specified time for Over Current protection, this one will not work, and the same thing is available if we decrease voltage level after worked first step of Automatic Re-close Equipment.
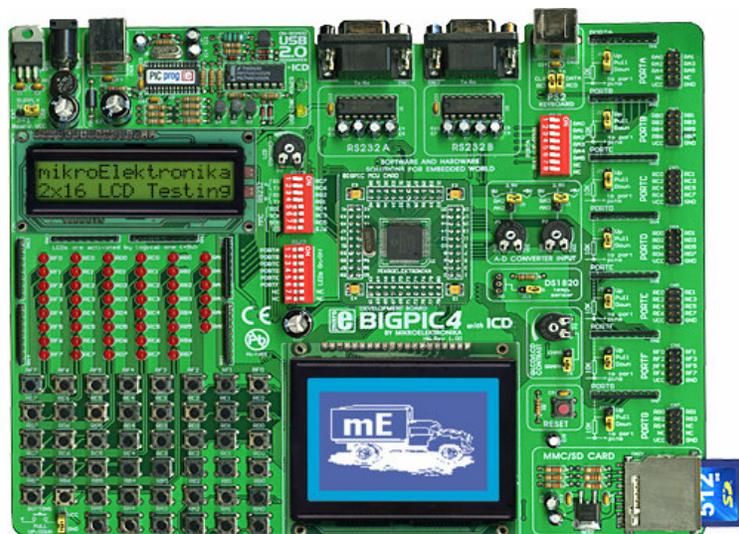

Figure 1. Development microsystem with PIC 18F8722 microcontroller

Finally, we use for simulating Automatic Tripping at Low Voltage Level, an alogical imput colected at pin RA1. This signal, comes also, from a 10 kΩ potentiometer (supplied from the board Vcc), and can

be changed in the range of 0V to 5V. For checking the protection function, we have to close Circuit Breaker and the specified LED will show the green color. By decreasing of voltage range, from the second potentiometer, we are able to simulate work of "Automatic tripping at low voltage level". Because, I placed protected 20 kV Over Head Line feeder, in the first level of supplying importance, when we decrease voltage level at the specified value, on the Ascii LCD will appear indication: "Automatic tripping at low voltage level II", which means that are disconnected all feeders of second level of supplying importance. If we continuing voltage decreasing, at specified value, will trip Circuit Breaker of simulated feeder, followed by LED red color and Ascii LCD "Automatic tripping at low voltage level I" indications.
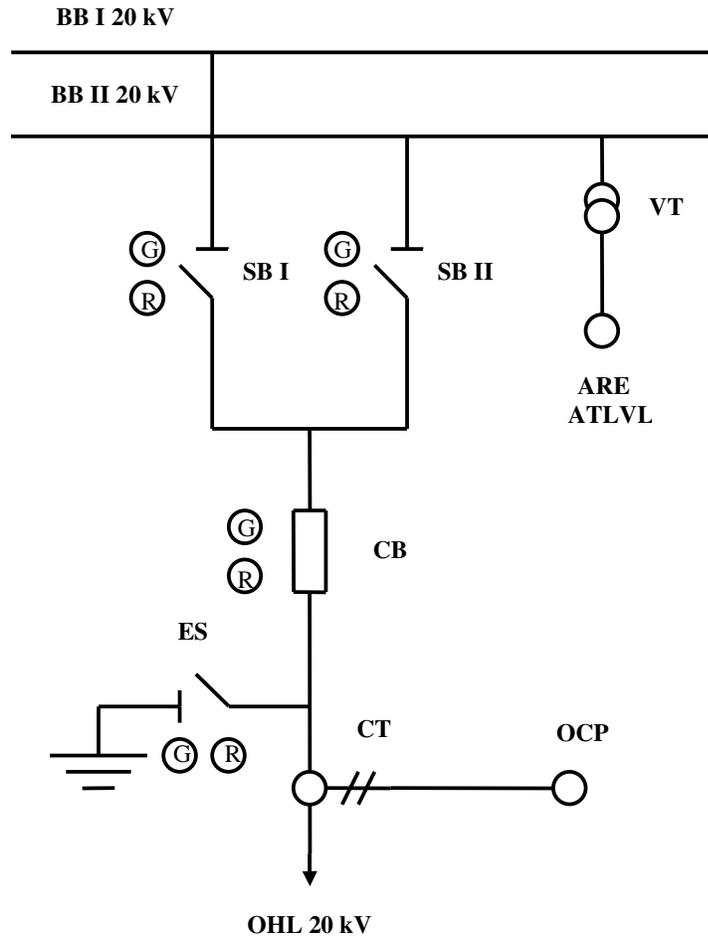

Figure 2. Single line drawing of Over Head Line Feeder of 20 kV

C. Coordinated systems of alarm and control

This part of application provides simulation of direct and remote connections of Circuit Breaker, Bus Bar Isolation Switches and Earthing Switch, together with their own interlocks and alarm informations. Are, also used few automations which brings the Over Head Line in the state of disconnected with Earthing Switch closed and the vice versa, meaning connecting the line to the Bus Bar 1 or Bus Bar 2 supply from the disconnected state with Earthing Switch closed. The figure.3. shows the parts of development board where are made the connections of simulating elements as follows:
1. PORT A with 2 analogical imputs and 4 digital imputs used for potentiometers and local switches;
2. PORT B with 8 digital outputs, used for LCD connection;
3. PORT C with 8 digital outputs used for LED's signals;
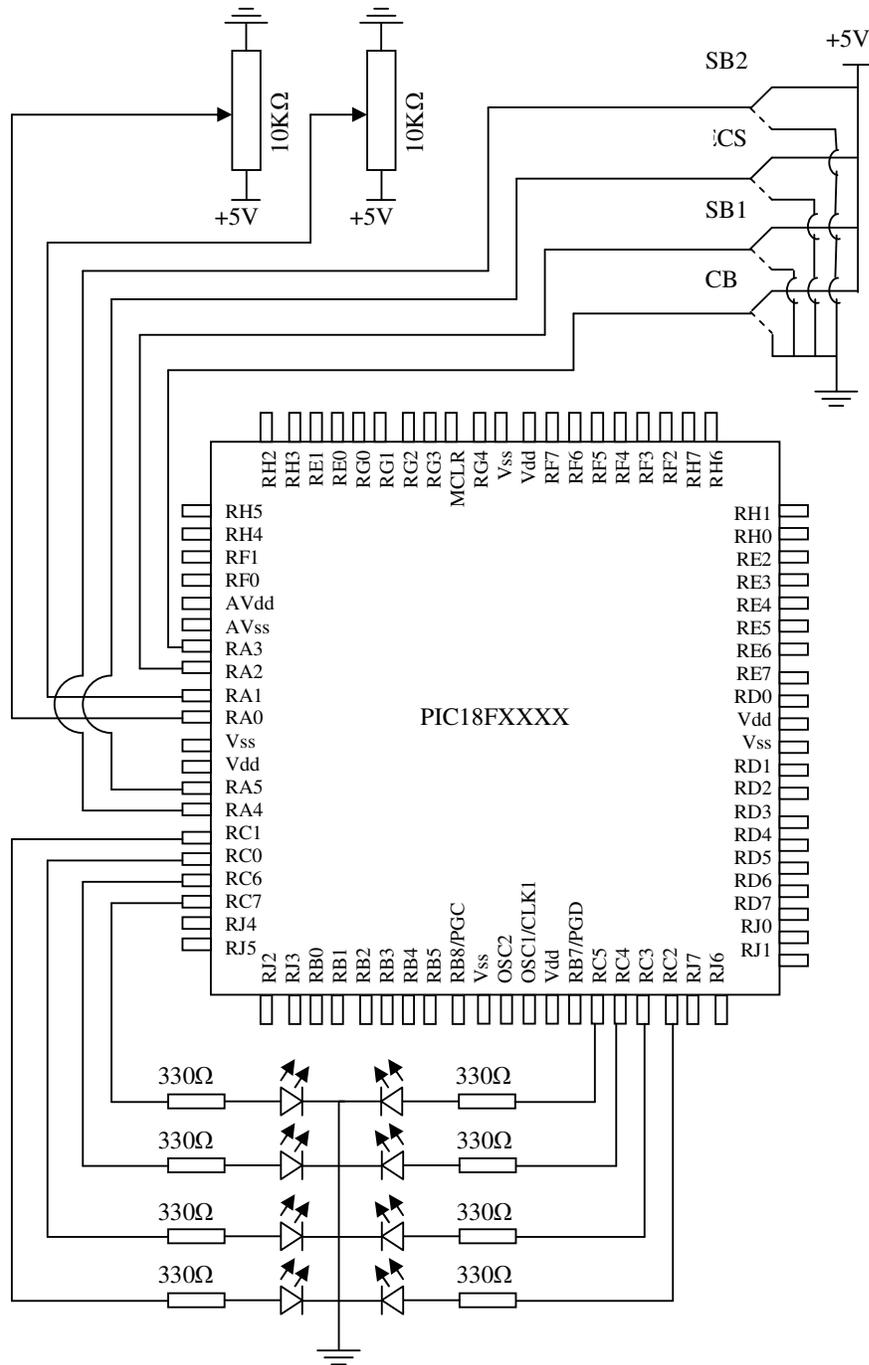4. PORT D with 8 inputs used for remote commands.

Figure 3. Practical drawing for LED's, CB, Switches, LCD and potentiometers connections at micro-controller imputs and outputs

As I mentioned before, because of the interlocks, we are not able to do what operation we wish, but only the operations allowed to bring the feeder in a safe state: closed or opened. For example, the program is made in that way that we cannot close the Earthing Switch, if the Circuit Breaker is closed and, also, we cannot open any of Bus Bar switches. Also, if we have the Earthing Switch closed, we cannot close the Circuit Breaker and if we have one of the Bus Bar Switch closed, we cannot close the second Bus Bar Switch. Finally, I will mention few words about automations which brings, for example, the Over Head Line in the state of disconnected, with Earthing Switch closed. This operation, can be done by remote, connecting a single button and all the operation is made in proper order: first will be opened the circuit breaker, after that will be opened the Bus Bar Switch, and, at the last, will be closed the

Earthing Switch. Reverse operation, can be done automatic or manually, of course with respect of proper operations. In all the operation stages, on the Ascii LCD will be shown the state of each operated switchgear followed by the LED indications (green or red).

D. Description of application for power quality indicators analysis

A quality system represents a group of regulations regarding organizational structure, responsabilities, actions and resources required to implement quality management. This group of regulations must represent legal base of consumers protection and they define clear obligations and responsibilities for all business partners involved in production-consumption route. Unlike the other activities sectors, power quality depends not only by producer but by all consumers connected at the some electricity network, some of them being able to to exert an disturbing influence to the supplier network, which is able to put out of balance another consumers supplied from the some network. In order to prevent disturbing influence of the producers, suppliers or consumers over the power network and to make an analysis of the phenomenon, so that beeing able to take measures to reduce it, I tried to develop the third application using the development microsystem presented in figure 1, connected to low voltage network through 6 transformers: 3 for voltage and 3 for current (connected at PORTA), displaying: rms, extreme and average voltages and currents, power factor, φ, sin φ, tan φ and active, reactive and apparent powers.

```
                    ┌──────────────────┐
                    │  Testing Device  │
                    └────────┬─────────┘
                             │
                    ┌────────▼─────────┐
                    │   Main Screen    │
                    │ RD7. Voltages display
                    │ RD6. Currents display
                    │ RD5. Power factor
                    │ RD4. Powers display
                    │ RD3. Back to Main Screen
                    └──────────────────┘
```

Testing Device

Main Screen
RD7. Voltages display
RD6. Currents display
RD5. Power factor
RD4. Powers display
RD3. Back to Main Screen

Phase R Pharameters Tensions
1. Urms =
Diversion Urms (%)
2. Upp =
Diversion Upp(%)
3. Uav=
Diversion Umd(%)

Phase R Pharameters Currents
1. Irms =
Point out maximum values
2. Ipp =
3. Iav=

Power factor
1. φ =
2. sin φ =
3. cos φ =
4. tan φ =

Phase R Pharameters Powers
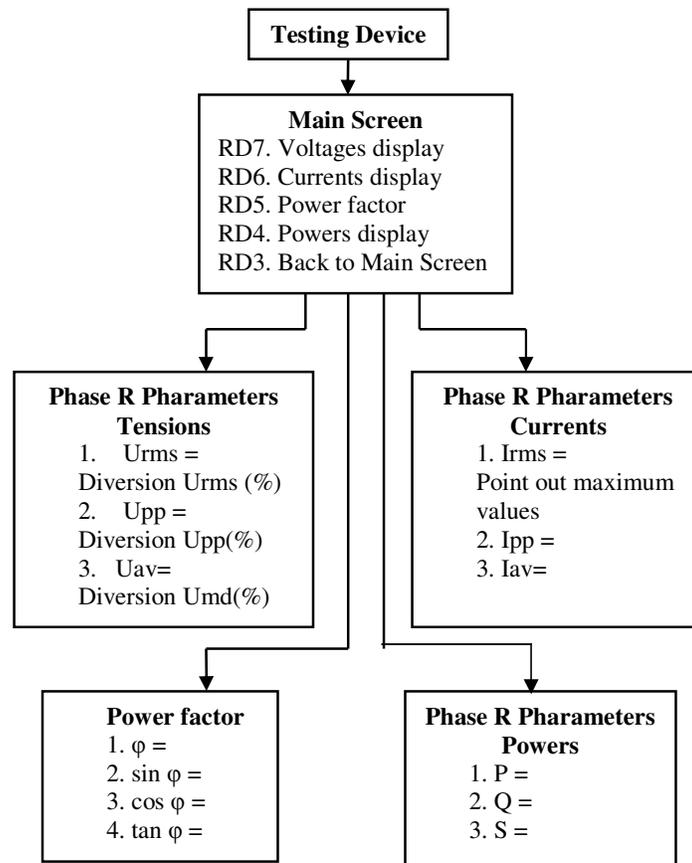1. P =
2. Q =
3. S =

Figure 5. Principal analysys of Power Indicators

Because development System can receive only a positive voltage, in range of 0V to 5V, it is necessary to add a value of 2.5 offset voltage, which is subtracted after acquisition and A/D transforming. For calculating rms voltage and current values, we used formula:

$$U_{ef} / I_{ef} = \sqrt{\frac{1}{T} \int_0^T x^2(t)dt} \qquad (1)$$

and for calculating average values, we used equation:

$$U_{av} / I_{av} = \frac{1}{T} \int_0^T x(t)dt \qquad (2)$$

For calculating $\int_0^T x(t)dt$ integral, we used approximation:

$$\int_0^T x(t)dt = \left(\frac{\frac{T}{n}(x_1 + x_2)}{2} + \frac{\frac{T}{n}(x_2 + x_3)}{2} + ... + \frac{\frac{T}{n}(x_{n-1} + x_n)}{2} \right) = \frac{T}{2n}(x_1 + 2x_2 + ... + 2x_{n-1} + x_n) \quad (3)$$

were n is number of counters and T is period of a complete waveform. For calculating power factor, we used formula:

$$\varphi = 360 \frac{\Delta t}{T} \qquad (4)$$

were Δt is voltage and current waveform delays.

II. Conclusions

Assuming above prezentation (especially the advantages comparing with another methods), I am able to underline that using this application together with mikroBasic operating system, we can improve students practical training together with High Voltage Substations performances. I have used this solution because, by combining those three operations (control, protection and power quality analizes), we are able to:
1. Introduce this application in practice, more easier than complex ones;
2. Change parameters in one fast way, due to computer interface, loading them after modification, into the development board memory;
3. Find and replace faults faster, because the simplicity of the used combined system;
4. Reduce cost of implementation, because lower investitions than traditional protection and command circuits of integrated or coordinated systems;
5. Renew old Substations equipments, step by step, depending of money available for investitions;
6. Use one friendly operating system such mikroBasic, which provide the customer with the easiest solution for developing applications.
7. Improve the power network quality parameters (voltage level on the remote points, peaks, hollows and voltage interruptions, peak currents etc).
8. detect the disturbing influence of the producers, suppliers or consumers in order to fine them (according to future expecting standards) if not respect defined Power Network quality standards.

From the other way, this application presents benefits for students from Electrical Universities' training, because of small construction and mobility, comparing with former applications which were done using big cases with relays or with integrated applications which are more expensive.

References

[1] Emanuel S. Savas, *Computer using for industrial processing supervisory*, Printing house Tehnica, Bukarest, 1969.

[2] Moga Mihai, *Intelligent systems for remote leading of distribution electrical network*, Printing house Agir, Bukarest, 2000.

[3] Nebojsa Matic, "PIC Microcontrollers", *MikroEctronika*, pp.50-60, 2006.

[4] Miron Alexandru, *Relays protections and automations in electrical networks*, Printing house Suceava University, Suceava, 2004.

[5] Mihaela Iordache, Ion Conecini, *Power network quality*, Printing house Tehnica, Bukarest, 1997.

[6] Ion Conecini, *Improvement of power network quality*, Printing house Agir, Bukarest, 1999.

[7] Gheorghe Georgescu, Mihai Gavrilaş, Daniela Rădăşanu, *Calculation and reducing the power wastage in electrical network*, Printing house Spectrum, Iassi, 1997.

[8] Gabriela Raţă, *Monitoring technics of power network quality*, Printing house University Steven the Great, Suceava, 2007.

[9] ***,"EASY PIC – 2 Manual", *MikroEctronika*, may, 2004.

[10] ***,"Power quality", *Aplication guide*. www.cda.org.uk