Monitoring, Protection and Control System for Medium Voltage Electrical Stations of 20/6 kV

Mircea DOBRICEANU, Alexandru BITOLEANU, Mihaela POPESCU, Eugen SUBTIRELU, Octavian Dan DOBRICEANU
Faculty of Electromechanical, Environment and Industrial Informatics Engineering, University of Craiova
107, Decebal Street, RO-200440, Craiova, Romania
mdobriceanu@em.ucv.ro abitoleanu@em.ucv.ro mpopescu@em.ucv.ro esubtirelu@em.ucv.ro ddobriceanu@gmail.com

***Abstract*—The continuity of the electrical power supply is very important to consumers especially in the industrial sector. The task of the protecting technique is to guarantee safe operation of the electrical energy systems by use of protective equipment specific to the operating plant, which quickly and selectively separates the affected operating device from the electric mains if dangerous states occur. The new multifunction digital protection relays using the processing power of the present generation of microprocessors, have a very high functionality. Many functions can be integrated into one device, allowing new power system problem solving capabilities while permitting significant cost savings as compared with discrete protective relays, instruments, meters, recorders and transducers of the past. In this way, the paper describes medium voltage electrical stations in which there is going to be implemented an automated monitoring system formed of local data acquisition, protection and control equipments mounted at the level of each cell within the electrical stations.**

***Index Terms*—Process monitoring, Power system protection, Power system control, Electrical equipment industry, Power transformer protection.**

I. INTRODUCTION

In medium-voltage engineering, there are typical applications such as feeder protection, line differential protection and bus protection. Each of these applications has a variety of specific functions, which were only covered in the past by the combination of a number of devices with individual functions.

The objective of the further development was to generate a high-quality protection and control system integrating numerous functions in one system and thus taking over practically all the tasks for a specific application, e.g. for feeder protection, cable/line differential protection or transformer differential protection.

The current devices combine all the benefits provided by modern digital technique to fulfill the variety of complex demands made of it on the part of the electrical supply utilities and industry.

Tasks entailing the protection of the operating plant, supervision of the system, detection and provision of measured values and messages for cases of operation, recording and evaluating measured values and messages for disturbances, control and locking functions as well as various possibilities of communication are to be mentioned here as being of great importance.

Alongside the consistent use of digital technique, high availability thanks to permanent self supervision of the devices, high functionality and flexibility as well as ergonomically designed user interfaces (MMI) are in the foreground as the system idea. In this way there appears the necessity of developing multifunctional intelligent equipments, with capabilities of acquisition and process of the monitored measures and extended communication possibilities, for real time supervision, destined to permanent monitoring, including processing procedures in accordance with the international standards and which integrate in the automation systems of the transformation station, with the purpose of protection, control and supervision of the electrical energy quality.

This paper describes some applications of the combined protection and control equipments for medium voltage electrical stations of 20/6 kV, [1], [2], [3], [8], [9].

II. MEDIUM VOLTAGE ELECTRICAL STATIONS OF 20/6KV

There is presented a medium voltage (20/6kV) station, using its schematics (Fig.1).

The station is supplied through an electrical line of 20kV and has 8 output lines for supplying the consumers (Supply Line1…Supply Line8).

For each input and output station lines there are provided switching equipments which assure the coupling of the inputs and outputs from the station according to the consumer's requests.

For supplying the consumers, the station is provided with two identical cell sections, (C6.1…C6.6 and C6.9…C6.14), with the following characteristics:

- each set of cells works independently being supplied from the TRFO1 and TRFO2 transformers;
- the two groups of cells are coupled between them through cells C6.7 and C6.8 and in this case the consumers are being supplied from TRAFO1 or TRAFO2 according to the state of the switching devices within the cells C20.3, C6.1 and C20.4, C6.14 respectively.

For the safety functioning of the electrical medium voltage station of 20/6 kV there are used:

- two types of protection and command equipments:
  - for transformer supply cells there are used differential protections for assuring the protection of the TRAFO1 and TRAFO2 voltage transformers.
  - for the consumers supply cells there are used line

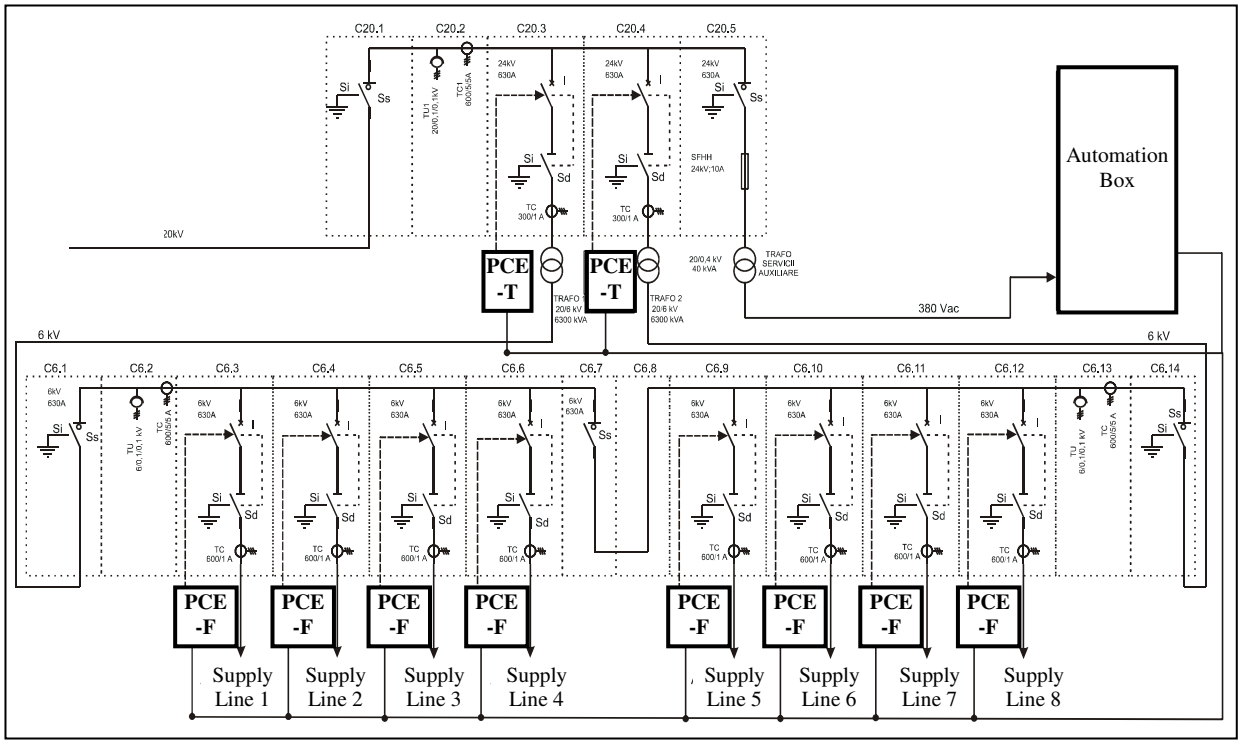

Fig. 1 Schematics of a electrical transformation station of 20/6 kV

protections which assure total protection of the consumers supplied on the respective line.

- and an Automation Box which contains the following elements:
  - secondary voltage supply circuits;
  - Programmable Logic Controller (PLC) which assures the functioning of the station in any chosen work mode;
  - dedicated equipments for acquisitions and transmission of the energetic data to the dispatcher.

III. PROTECTION AND CONTROL EQUIPMENT - PCE

Using the achievements within the digital processing technical domain and most of all within the high speed communication domain, there can be built a multifunctional equipment for acquisition, command, automation and protection at the cell level, which is interconnected in the data network with the processing equipments at the station level [10], [11].

A. Architecture of the PCE

The transformer supply cells and the consumer supply cells are quipped with such equipments that are:

- trafo differential protection and control system (PCE-T);
- feeder protection and control system (PCE-F).

The protection and control equipment (Fig.2), contains the following two distinct units:

- one main unit in which there are implemented all the necessary functions and interfaces for acquisition, protection and control;
- one display and operating unit which is used as "Man-Machine Interface" (MMI).

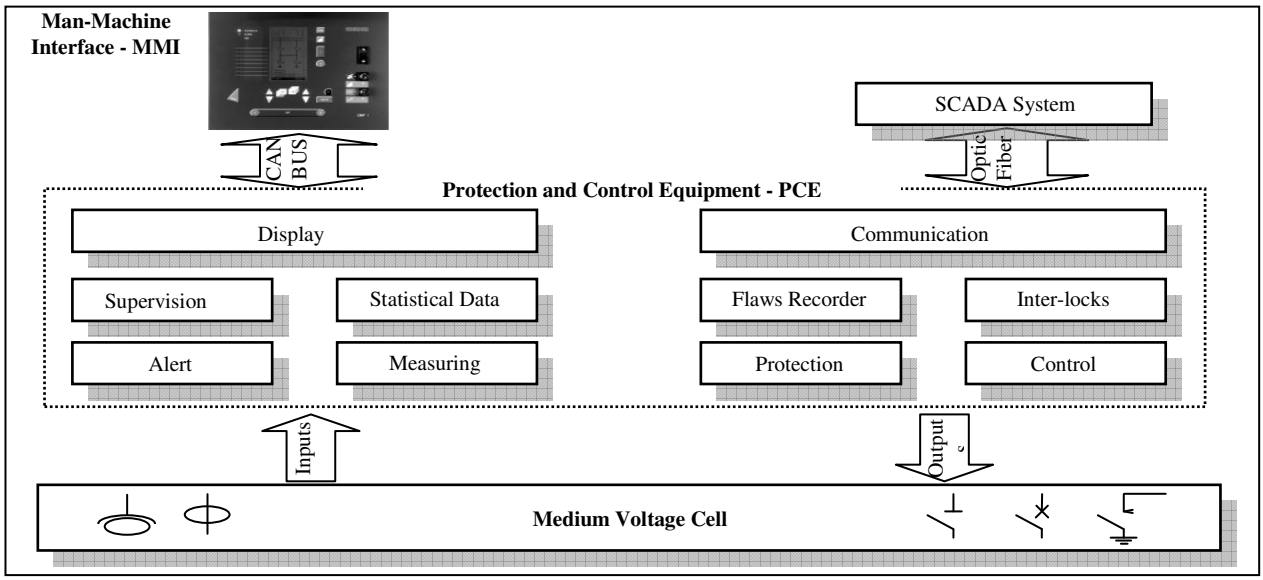

Fig. 2 Block diagram of the protection and control equipment for an electrical cell

The communication between the two devices is done via a CAN field bus system.

The main unit is implemented directly, in a medium voltage cell, without using intermediary command relays, thus reducing the manufacturing cost of the respective cell.

The main unit can also work independently, with the need to be coupled to a display and operation unit of MMI type.

The system can also function within an integrated SCADA system, to which it is connected through a RS485 link or using an optical fiber link.

Access to the systems is done via a central PC, making use of the application software, this way enabling comfortable operation: data read, securing disturbance records as well as (remote) parameterization of the connected devices.

The local operation with the protection and control equipment is realized using a display unit which is usually installed on the front panel of the medium voltage cell (Fig.3). Using this there can be rapidly accessed the operating data of the switching equipments (switches, separators), local parameterization of the protection functions of the system and local command of the switching elements.

B. Functions of the PCE

The protection and control equipment assures the following functions:

- Protection function:
  - Over current directional/non-directional;
  - Short circuit current directional/non-directional;
  - Ground current directional/non-directional;
  - Cable/Line differential;
  - Overload with thermal replica;
  - Residual voltage;
  - Over-/Under voltage;
  - Over-/Under frequency;

Fig. 3 Display and operating unit, integrated in the medium voltage cell

  - Automatic Reclosing (AR);
  - Programmable protection logic;
  - Voltage transformer supervision;
  - Reverse interlocking;
  - Lock out function;
  - Switch of parameter sets.
- Control functions:
  - No. of recognizable switching devices: 5;
  - No. of controllable switching devices: max. 5;
  - No. of power outputs for control of motor-driven switching devices: 2;
  - No. of signal relays: 6;
  - No. of configurable digital inputs: 22;
  - Command outputs with defined switching and operating times.
- Supervision functions:
  - Fault/differential position;
  - Withdrawal of the circuit breaker;
  - Programmable interlocking conditions at feeder level;
  - Interlocking of switching devices at station level by SCADA system.
- Programmable logic functions:
  - 32 programmable logic equations;
  - 32 input variables per logic function
  - 1 time element per logic output.

C. PCE – T as a field management system for transformer differential protection

For achieving the acquisition, command and protection functions, in case of 20/6kV transformer supply cells, there were used equipments of type PCE-T in combination with the MMI interface, an equipment mounted in cells C20.3 (TRAFO1 supply) and one in C20.4 (TRAFO2 supply) respectively. These equipments assure classical protection functions, and also the automatic recording of the defects and differential protection function needed to protect the supply transformers of the electrical station in case there are spotted differences, which go over the programmed limits, between the currents within the transformer's primary and secondary.

There is presented the basic functioning schematic of the differential protection (Fig.4) and the scheme with connections (Fig.5) using the protection and control equipment PCE-T, [11].

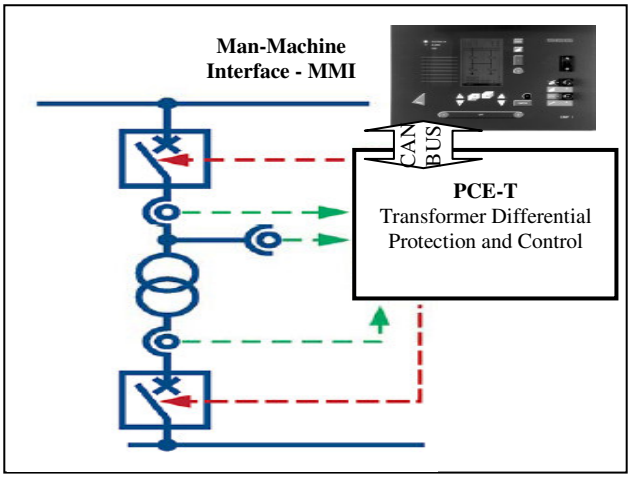

Fig. 4 PCE-T for transformer differential protection

The measurement of the current in TRAFO1 transformer's primary is realized by applying at the X7.1… X7.10 inputs the signals from the output of the transducers mounted on each output phases within C20.3 cell (respectively, C20.4 for TRAFO2).

The measurement of the current within the TRAFO1 transformer's primary is realized by applying at the X7.11… X7.22 inputs the signals from the output of the transducers mounted on each output phases within C6.1 cell and respectively, C6.14 for TRAFO2.

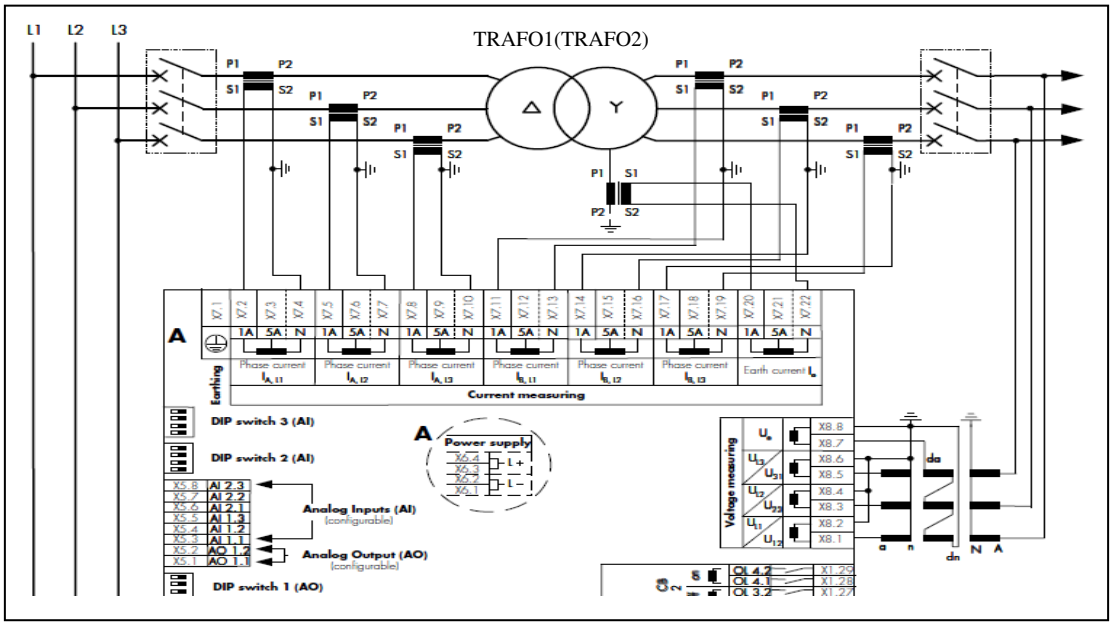

Fig. 5 Connection diagram PCE-T

The measurement of the voltage is realized by applying at the X8.1…X8.8 inputs the signals from the outputs of the voltage transducers.

D. PCE - F as field management system for feeder protection

For achieving the acquisition, command and protection functions, in case of the cells for supplying the consumers there were used equipments of PCE-F type in combination with the MMI interface, one equipment mounted in the C6.3…C6.6 cells, respectively one in the C6.9…C6.12 cells according to the basic functional scheme (Fig.6).

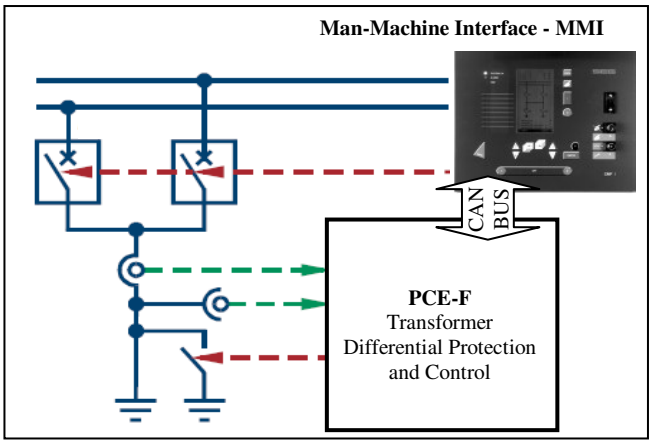

Fig. 6 PCE-F for feeder protection

There is presented the connection scheme for measuring the current and voltage using the PCE-F protection and control equipment (Fig.7).

The measurement of the current is done by applying at the X2.1…X2.12 inputs the signals from the outputs of the current transducers mounted on each of the three output phases within the line cells C6.3…C6.6, respectively C6.9…C6.12 cells.

The measurement of the voltage is realized by applying at the X5.1…X5.8 inputs the signals from the voltage transducers output.

E. Main menu of the PCE

The main menu of the combined protection and control equipment offers the following sub-menus:

- Measurement - The PCE offers the user measurement values which inform about the operational status of the MV-panel. Measurement values can be locally shown and read out at the display of the operation and display unit MMI. By using a SCADA-system or an automation system, the measurement values are transmitted as data points (telegrams) of the corresponding protocol type.
- Statistics - In this menu the so-called "statistical data" can be read out which give information about the load flow for defined periods of time during the operation of the MS-panel.
- Event recorder - The event recorder records up to 50 events referring to the corresponding medium voltage panel. These include protection, control, parameter setting and self-test events. Beside the name of an event also further data are saved which permit more exact conclusions from the event. The event recorder works according to the FIFO-principle.
- Fault recorder - The "Fault recorder" saves data which are related to a trip (also-called "Fault" or "Disturbance"). The memory of the fault recorder guarantees the recording of up to 5 disturbances. For each disturbance event the measurement values at the time of the tripping (instantaneous recording of the fault values) are additionally recorded in form of absolute values.
- Disturbance recorder - Contrary to the fault recorder, which only saves the fault events and records the relevant measurement values at the time of tripping (instantaneous fault recording), the disturbance recorder function makes possible the recording of limited time histories of analogous and digital channels.
- Status - Within the status menu, the status of the signal outputs (signal relays), function inputs (digital inputs) and logic outputs are shown within the corresponding sub-menus.

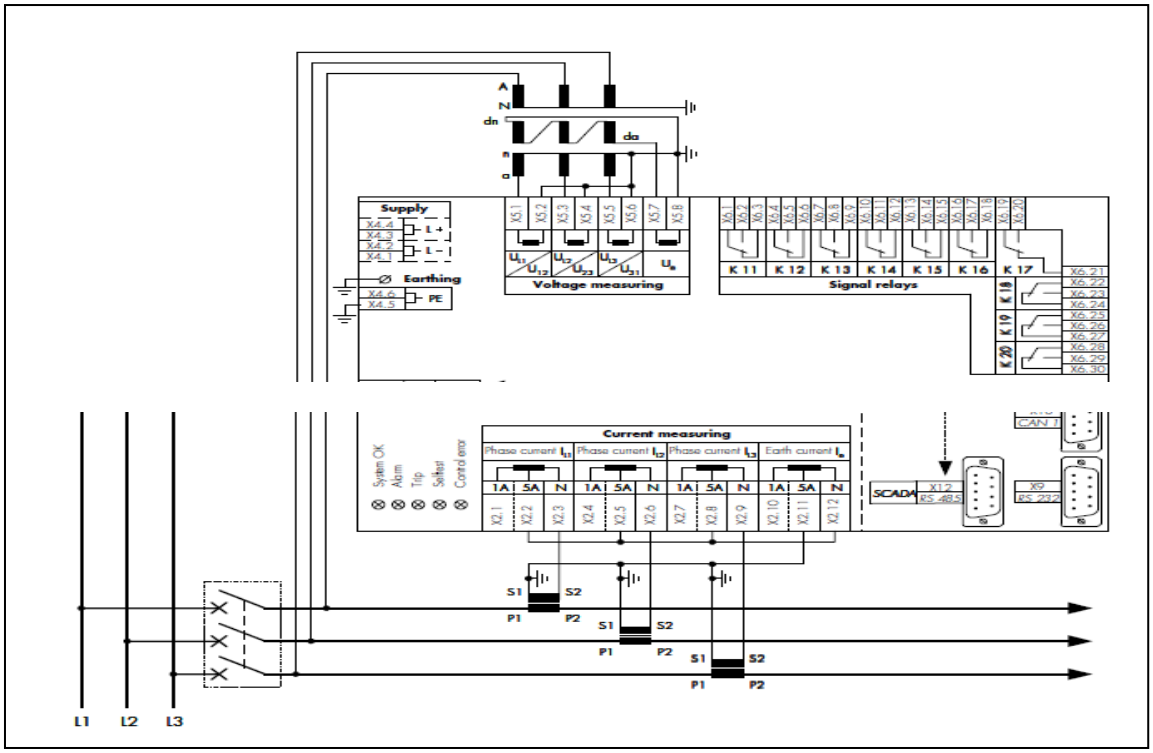

Fig. 7 Connection diagram PCE-F

- Service - In the "Service" menu, important device data for the PCE system and revision data for the MV switchgears of the cubicle are displayed.
- Parameter - The individual parameters and their settings are explained with their effects on the total system.
- Self test - With the self-test, functions the PCE can be tested. Each test function is shown on the display during its execution via Popup windows.
- LCD setting;
- Device selection.

F. Communication

The connection of the combined protection and control equipment (PCE) with the SCADA system via the communication variants PROFIBUS DP is based on Standard EN 501702.

The data protocol PROFIBUS DP is the most frequently used communications protocol in industrial bus systems due to its high transmission speed, efficiency and the optimized and thus lower connection costs. It is especially suitable for the communication between the decentralized periphery devices (field level) and the different automation systems (station level).

The linking of the PCE equipments with PROFIBUS DP enables the inclusion of medium voltage applications in the automation world like building or process control engineering.

The connection of the combined protection and control equipment (PCE) with the display and operating unit (MMI) is realized by the CAN-BUS-system.

The communication port for direct PC connection using the interface software is a standard RS-232 port. It is used to download settings and configuration data from a PC to the PCE in the field, and also for local access to event reports and waveform capture buffers.

IV. COMMAND AND DATA RECEIVER SYSTEM FOR THE MEDIUM VOLTAGE ELECTRICAL STATION

Taking over data from the medium voltage electrical station and also the command of the switching elements within the component cells is realized with a system organized on two levels (Fig.8), [4], [5], [6], [7].

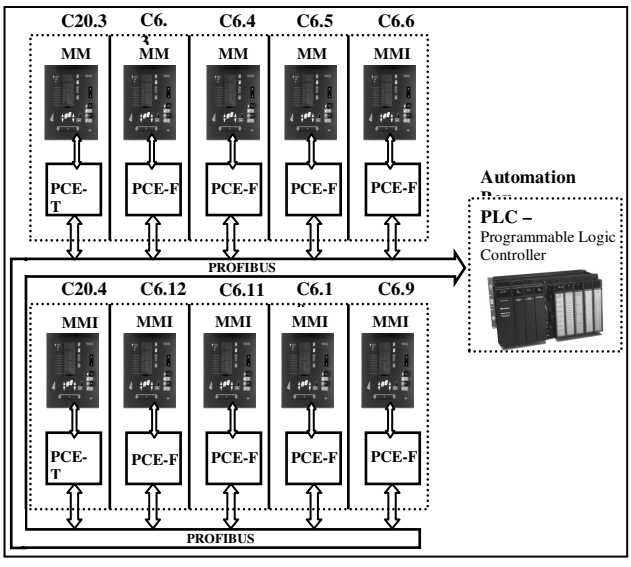

Fig. 8 Block diagram of the data command and receiver system

- Level 1: contains data acquisition protection and control equipments, mounted at the level of each cell within the electrical distribution station. Each one of these equipments acquire data referring to the electrical parameters (currents, voltages, powers, switching elements state, protection state at that respective moment, statistical data, etc) of the respective cell.
- Level 2: is represented by the Programmable Logic Controller (PLC) mounted in the automation unit. This

assures the mixing of the data referring to the functioning of all elements within the station, data that are used in two main ways:

- providing input data for the program that is implemented in the PLC which coordinates the functioning of the station;
- providing data, using the data communication subsystem, for the SCADA system implemented at the dispatcher level, when this is needed.

V. MAN-MACHINE INTERFACE - MMI

The operating panel – at the PLC level – is an "Embedded PC" that has a monochrome graphic display with a 320x240 pixels resolution with a sensitive panel, on which runs a Windows CE OS. On the display there are shown a series of successive screens by the help of which there are visualized the main parameters referring the functioning of the station.

On the main screen (Fig. 9) there is displayed a schematic of the electrical station with the presentation of the switching elements from the level of each medium voltage cell, presentation of the input of the station (supply with 20 kV) and also of the output of the station (consumers supply with the voltage of 6 kV).

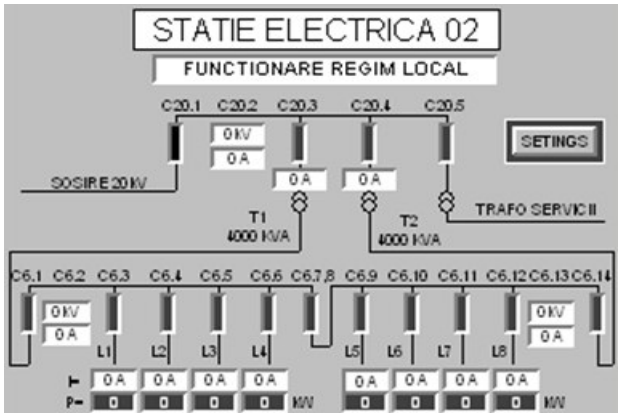

Fig. 9 Main screen displayed on the operator panel

By pressing the "SETINGS" button, the user has access to a special window (Fig. 10), for setting the following parameters: Date and time; Display parameters; Power settings on each of the 8 consumer supply lines within the electrical station by pressing the "SETARI PUTERI PE LINII DE ALIMENTARE" button.

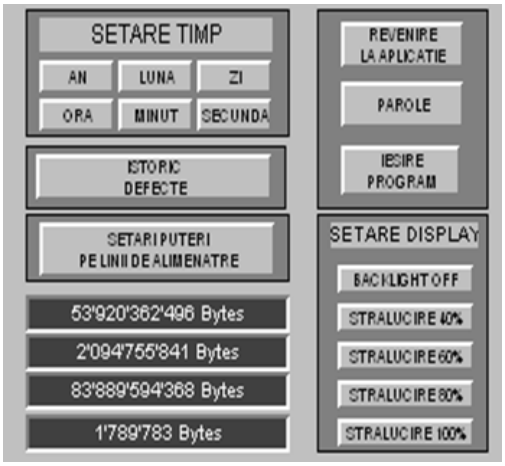

Fig. 10 Parameter setting screen

VI. CONCLUSION

The innovation level of the presented system is reflected by:

- Integration of many functions into one numerical equipment, resulting in lower cost, less wiring and testing, and reduced panel space;
- MMI for local keypad operation, with large LCD display to show settings, metering, event data and graphics;
- Uploading and downloading of data and logs using a PC;
- Possibility of adapting the system for each user;
- The distributed system that is described was built, is installed and properly works in a High Technology Electrical Transformation Station from Romania.

ACKNOWLEDGMENT

This work was supported by the National University Research Council (CNCSIS) of the Romanian Minister of National Education. It is part of a project covering theoretical and applicative researches on Distributed Systems using Intelligent Techniques for Monitoring Electrical Stations: ID 527/2008.

REFERENCES

[1] D. Bailey, E. Wrigh. Practical SCADA for Industry. Elsevier, ISBN:0-7506-5805-3, 2002.

[2] M. Dobriceanu. Data Acquisition Systems and Microprocessors (Ro), Ed. Universitaria Craiova, 2003.

[3] J. Stokoe, T. Cumming, B. Hood, W. Carr, Development of a Strategy for the Integration of Protection, Control and Monitoring Equipment, Session 2002 CIGRE, pp. 34 -102, 2002.

[4] M. Dobriceanu, A. Bitoleanu, M. Popescu, G. Vlăduţ, "Automated Data Acquisition System for Monitoring Electrical Stations", 12th International Power Electronics and Motion Control Conference – EPE-PEMC 2006, Slovenia, Proceedings (CD: 1271 T7-201), IEEE Catalog Number: 06EX1282C - ISBN 1-4244-0121-6, August 30-September 1, 2006.

[5] M. Dobriceanu, A. Bitoleanu, M. Popescu, S. Enache, G. Vlăduţ, "Method and System for Monitoring the Power Quality in Electrical Distribution Stations", International Aegean Conference on Electrical Machines and Power Electronics and Electromotion Joint Conference, – ACEMP07, Electromotion07, Bodrum, TURKEY, Proceed.ISBN: 978- 975-93410-2-2, pp. 526- 531, Sept. 10-12, 2007.

[6] M. Dobriceanu, A. Bitoleanu, M. Popescu, E. Subtirelu, S. Enache; "Combined Protection and Control Equipment for Applications in the Medium-Voltage Area", 19-th International Symposium on Power Electronics, Electrical Drives, Automation and Motion – SPEEDAM 2008, Ischia - ITALY, Proceedings (CD: PS1087), IEEE Catalog Number: CFP0848A-CDR, ISBN 978-1-4244-1664-6, June 11-13, 2008.

[7] M. Dobriceanu, A. Bitoleanu, M. Popescu, E. Subtirelu, O. D. Dobriceanu; "A Distributed System Using Intelligent Techniques for Monitoring Electrical Stations", International Electric Machines and Drives Conference (IEMDC 2009), Miami, Florida, USA, Proceedings (CD: 10856), IEEE Catalog Number: CFP09EMD, ISBN: 978-1-4244-4252-2, Library of Congress: 2009901995, pp 1744-1749, May 3-6, 2009.

[8] J. Stokoe, T. Cumming, B. Hood, W. Carr, Development of a Strategy for the Integration of Protection, Control and Monitoring Equipment. Session 2002 CIGRE, pp. 34 -102, 2002.

[9] Y. Tingfang, Z. Xiangjun, L. Pei, T. O. Ting, H. R. Cai, "Design of Multi-Function Monitoring Integrated Device in Power System", IEEE Industry Applications Conference, 2007.

[10] K. Brent, P. E. Duncan, G. Bruce, "Protection, Metering, Monitoring And Control Of Medium Voltage Power Systems", Siemens Power Transmission & Distribution, Inc Siemens Power Transmission & Distribution, Inc Distribution Products Division, P.O. Box 29503, Raleigh, NC 27626-0503 USA.

[11] [xxx], Combined protection and control system, SEG – Schaltanlagen-Elektronik-Geräte GmbH & Co. KG, Geschäftsfeld/Division Power Protection, Germany.