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PROGRAMMABLE LOGIC DEVICE FOR CONTROL AND PROTECTION IN THE ELECTROENERGETIC SYSTEMS

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Abstract : In this paper is having in view the improvement of the electroenergetic systems by a numerical protection equipment achievement in programmable logic which works both in the cell's level and in the station's level. The numerical solution of this protections is sustained by the low cost of the chips which are implemented in these equipments and by the offered advantage in the numerical processing in generally and especially in the programmable logic. After a short analyse of the achievement's principle of the protections and the control system of the electroenergetic system is proposed a numerical multifunctional equipment in programmable logic implemented with a microcontroller. This equipment can achieve multiple functions of measurement, protection, control and communication with a high level command.

Keywords : programmable logic device, electroenergetic systems, acquisition and processing, control, protection.

1. INTRODUCTION

The impossibility to storage of electrical energy on the industrial scale supposes a continual working of the primary equipments so that the specific parameters: voltage, current, frequency, active and reactive power etc, needs to be integrated, in the point of view of it's value, in certain limits. As a result of the action of the perturbations in the energetic system can appear some modifications of this parameter's values in out of the required limits. Sometime, even in the limits of the parameter's normal values, in necessary a deliberate modification of the transport and distribution network configuration.

The mentioned operations are ensured by the secondary circuits and they are translated effectively through the proper equipments which implements this operation's functions. The main functions associated them, are: sampling, processing, protection, control and signaling;

The sampling supposes to estimate the main parameters values of the energy: voltage, current, frequency, active and reactive power, active and reactive energy as well the obtaining of some information concerning to the switching equipments condition (logical information).

The sampled parameters values are processed according to the structure and purpose of the equipments, and processed results are used to achieve the protection, control and signaling functions.

By protections is achieved the getting out of function (automatically) of an installation case.

The control lay in the elaboration of some decisions, on the ground of the processing of the sampled signals, which is need to ensure the energy quality, the safety working, the connecting or disconnecting of some interrupters or separators, in some cases is need to achieve this function either automatically or manually.

The signaling function lay in the information concerning to the matching equipments condition, the damage and the damages' nature, the appearing of some abnormal regimes.

In the shape of the block diagram, the structure of such equipment can be represented according to figure 1.

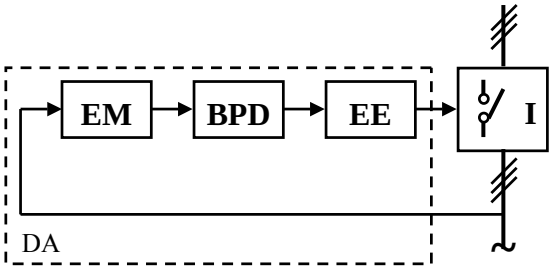

Fig. 1 . The block diagram of the control and protection equipments.

The block diagram represents in essence an automate system and contains : the measurement element (elements) (EM), the processing and decision block (BPD), the fulfilling element (EE) which give the control signal for the static power switch (switches) which achieves the disconnecting of the damage zone, the changing of the network configuration.

The processing and decision block (BPD) is implemented actually almost exclusively in cabled logic.

The type of the measurement elements depends of the equipment purpose and of the nature of sampled signals.

2. THE SYNTHESIS OF THE CONTROL AND PROTECTION BLOCK

If will be analyzed the interest parameters then will be found that, indifferently of equipment purpose, is enough to sample information regarding to the voltages and currents for obtain next the values regarding frequency phase, active and reactive power. This thing is possible if BPD is implemented in programmable logic.

The effective values of the voltage and current can be easily calculated using the Fourier series of a periodical function f(t).

The trigonometrically expression of the function is given by the following formula :

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left(a_n \cdot \cos n\omega t + a_n \cdot \sin n\omega t \right) \tag{1}$$

, where :

$$a_0 = \frac{2}{T} \int_0^T f(t)\, dt \tag{2}$$

$$a_n = \frac{2}{T} \int_0^T f(t) \cdot \cos n\omega t \; dt \tag{3}$$

$$b_n = \frac{2}{T}\int_0^T f(t)\cdot \sin n\omega t\, dt \tag{4}$$

The expression (1) can be restricted and obtain the harmonically form of the Fourier series :

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} A_n \cdot \sin(n\omega t + \varphi_n) \tag{5}$$

, with : $A_n = \sqrt{a_n^2 + b_n^2}$ (6)

$$\varphi_n = arctg\frac{a_n}{b_n} \tag{7}$$

For n = 1 will obtain the fundamental harmonic with effective value :

$$A = \frac{A_1}{\sqrt{2}} = \frac{1}{\sqrt{2}}\sqrt{a_1^2 + b_1^2} \tag{8}$$

, and initial phase :

$$\varphi_1 = arctg\frac{a_1}{b_1} \tag{9}$$

For computing these values is necessary to calculate the values a_1 and b_1 by expressions (3) and (4) and this supposes to know the analytical expression of the function f(t) and the integral calculus from the mentioned expressions.

By using the programmable logic, the function is described from samples; in this case, the function is described by the instantaneous values for a period T, obtained at equidistant themes given by the sampling theme Te, which imposes the conversion rate of analog-digital converter (CAN) too.

In this case, for N intervals on the period T, the integrals from previous expressions can be approximated by the sums of the instantaneous values $k \in$ (0, 1,…, n-1).

In this case, if will do the transformations :

$$\begin{aligned} dt &= T_e \\ T &= T_e \cdot (N-1) \\ t &= k \cdot T_e \\ \omega &= \frac{2\pi}{T} = \frac{2\pi}{T_e \cdot (N-1)} \end{aligned} \tag{10}$$

, the expressions for the effective value and the phase will be in form:

$$A = \frac{1}{\sqrt{2}}\sqrt{a^2 + b^2} \quad \text{and} \quad \varphi_1 = arctg\frac{a}{b} \tag{11}$$

, where :

$$\begin{aligned} a &= \frac{2}{T_e \cdot (N-1)}\sum_{k=0}^{N-1} f(k)\cdot \cos\left(\frac{2\pi}{N-1}k\right) \\ b &= \frac{2}{T_e \cdot (N-1)}\sum_{k=0}^{N-1} f(k)\cdot \sin\left(\frac{2\pi}{N-1}k\right) \end{aligned} \tag{12}$$

Sampling the voltage and current, the samples f(k) will be assimilated with the values of the voltage samples u(k), respective the current samples i(k).

According to the expressions (11) can be calculated the effective values and initial phase for the basic harmonic of the voltage (U, φ_U) and the current (I, φ_I) respectively.

If will be achieved the sampling in the same themes both the voltage then the current can be calculated the total out-of-phase :

$$\varphi = \varphi_I - \varphi_U \tag{13}$$

With this effective values and the (out of) phase is possible to determine using previous expressions, the active, reactive and apparent power.

For the synthesis of the multifunctional block for control and protection is needed to take into consideration the technical-functional specification which are required by the equipments tasks. In a concise mode, this specifications aim :

- sampling two analog signals(voltage and current, provided from the typical transducers ;
- sampling at least four digital signals which describe the state of the control and the protection equipments ;
- the possibility to command at least three relays for the commands can be transmitted in the shape of impulses ;
- the information processing is needed to be in the programmable logic ;
- for complex processing of same information is needed to exist the possibility to communicate with a higher computing level system ;
- is needed to ensure the required signals regarding to the serviced equipments, damages, abnormal of regimes of function ;
- reference level programming ;

On the ground of this specifications was synthesized the block diagram of the conceived device:

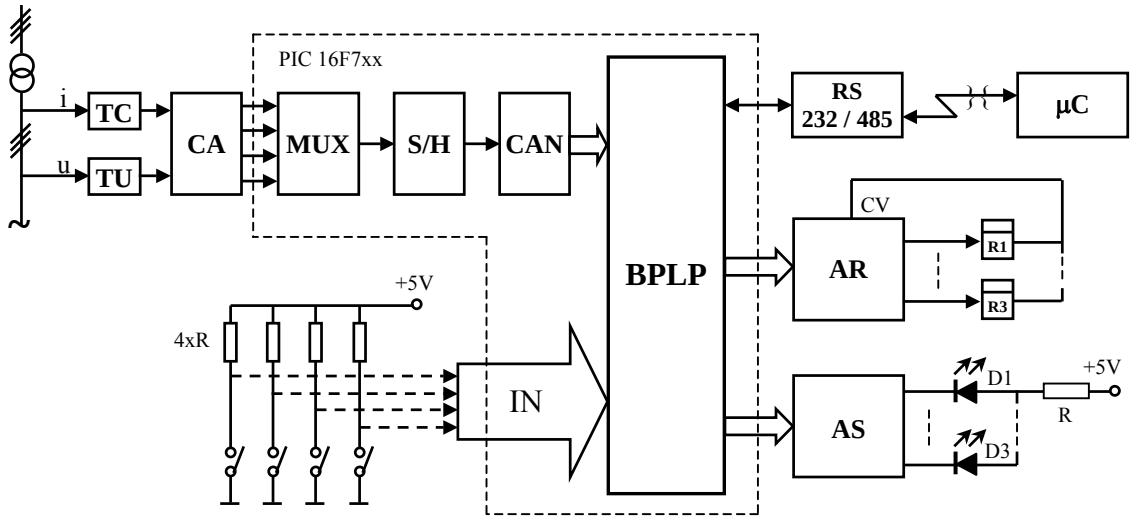

Fig. 2 . The block diagram of the multifunctional device.

Voltage and current transducers (TU and TC) represented by measurement transformers, used in the existent installations, were used for the voltage and current sampling. The signals provided by these transducers will be applied, through an adapter circuit (CA), to a multiplexer (MUX) and next, through the sample and hold circuit, it will be applied to an analog-digital converter (CAN). The result is taken and processed by the programmed logic processing block (BPLP) implemented with a microcontroller of PIC type.

Besides the analog signals, four digital inputs are stipulated too for signal sampling referring to the serviced equipment state. The resulted commands from the processing of the input signals are translated through amplifiers (AR), to the relays R1...R3. The control of the switching equipments serviced by this device is achieved through the contacts of the input signals. The signaling signals are transmitted to the signaling diodes D1...D3 (LED) through the signaling amplifiers (AS).

This device can be connected to a higher computing level system through an interface IRS232 (485). Through this interface it is possible to transmit to the device the reference values or to take from the states respectively.

The adapter circuit (CA) ensures the compatibility between the signals form the voltage and current transducers and the input of the processing block. Besides this block contains a low-pass filter which permits to pass (cross) only the basic harmonic (50 Hz).

The structure of the block diagram of the adapter circuit is shown in figure 3.

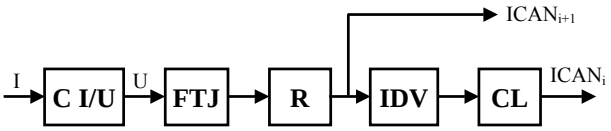

Fig. 3. The block diagram of the adapter circuit.

The adapter circuit contains a current voltage converter (e I/n-only for the current transducer).

The low-pass filter (FTS) is an active filter, projected for a maximum frequency of 80 Hz to permit the passing for the basic harmonic only. The resulting signal will be applied to a rectifier block (R).

When the device achieves protection or control (for the switching of the plots or other commands), the signal will be applied at the input of the analog-digital converter (CAN) through the integration and peak detector circuit (IDV) followed by a limiting circuit (CI).

However if, besides the protection function it is necessary to have the sampling function, then, from the rectifier block output, the signal will be applied in addition to another multiplexer input (form the CAN). Through this input will take the voltage, which is proportional to the measured value, the resulting samples will be stored in the date memory from where they will be transmitted to a higher computing level system.

The cross-down filter and the rectifier blocks are implemented with operational amplifiers (figure 4)

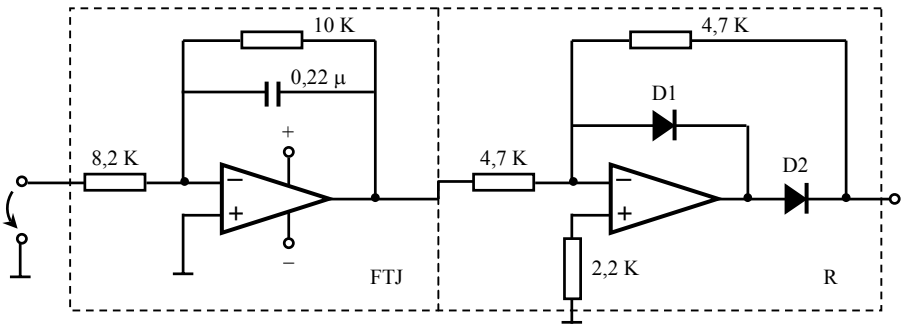

Fig. 4. The structure of the block FTJ and R.

The integrator, the peak detector (IDV) and the limiting circuit (CL) are achieved on the ground of the operational amplifiers too (figure 5).

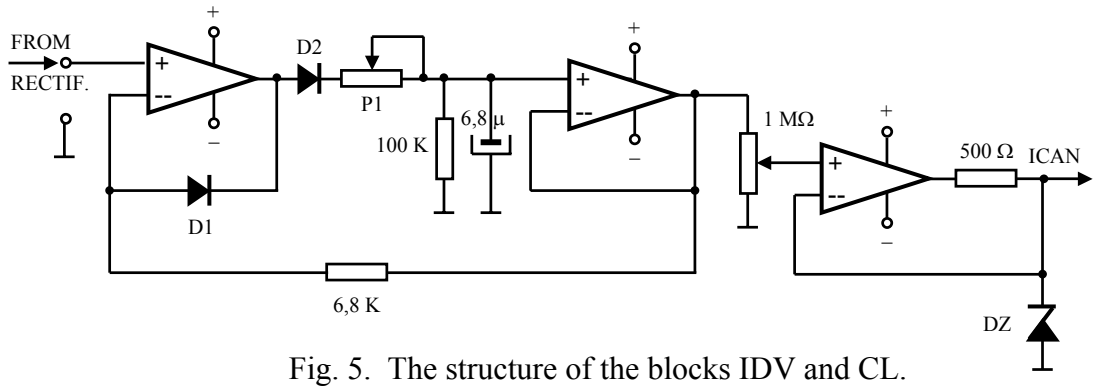

Fig. 5. The structure of the blocks IDV and CL.

The multiplexer (MUX), the sample and hold circuit (S/H) and the analog-digital converter (CAN) are integrated in the selected microcontroller structure.

The communication with the higher computing level system is achieved by a serial interface of RS 485 type to lengthen the communication distance, and at the receiving by a circuit which realizes the RS 485 / RS 232 conversion. The structure of the RS 485/RS 232 conversion block.

The conversion block is implemented with specialized circuits for this kind of the implemented functions (MAX 232 and S SN 74 LS 176).

The test was achieved only for short-circuit and overload protection function, using an external analog-digital converter (TLC 545) and a microcontroller (PIC 16F84).

3. CONCLUSIONS

The device multifunctionality is ensured by the flexibility given by the programmable logic. The implemented program depends on the purposes and the functions of the device. The purposes and the functions of the device not involves hardware changes, so that, the device can be used in varied applications.

The multifunctional features of the device is given by its facilities : acquisition, measurement, protection, communication with a higher level system.

The designed device ensures the decentralization of the control and protection systems, and it ensures too the acquisition and processing on the technological process level.

By communication with a higher level system, this device allows a complex processing of the primary data, achieving, in this way, the information concerning to the state, energy consumption and monitoring of the energetic systems.

REFERENCES

[1] Dusa V. , Vaida V. (2001) - Comanda si controlul functionarii retelelor electrice, Ed. Tehnica, Bucureşti

[2] Fotau I. (1999) - Electroenergetica - partea I. Ed. Universitas

[3] Poanta A. , Pătrăşcoiu N. (1997) - Circuite şi echipamente electronice în industria minieră, Ed. Didactică şi Pedagogică , Bucureşti

[4] * * * - Datasheets : PIC 16C/F8x, PIC 16C/F7xx, PIC 16C/F8xx.