Contributions to Achievement of Numerical Differential Protection

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***Abstract*—At present, power transformers of transformer stations are protected by differential electromagnetic relays RDS or numeric relays P63x and GRT 100. Experimental studies in the differential protection area go to the introduction of the fuzzy logic differential relays.**

***Index Terms*—microprocessor, protective relay, transducer, transformer**

I. INTRODUCTION

According to norms [1] power transformers are fitted with the following protection:

- protection with gas relays, for transformers with oil with power S > 1000 kVA
- longitudinal differential protection, S≥6,3 MVA or S<6,3MVA (transformer in parallel);
- simple protection maximum current (Chevalier protection or the protection of vat);
- maximum current protection timer with or without blocking minimum voltage and distance protection (the distance protection for the Trafo U ≥ 220 kV);
- maximum protection of current or voltage removal timer;
- current maximum protection without blocking voltage minimum delay;
- protection against over temperature.

Electric scheme of principle of a differential longitudinal protection of transformer or autotransformers is shown in Fig. 1.

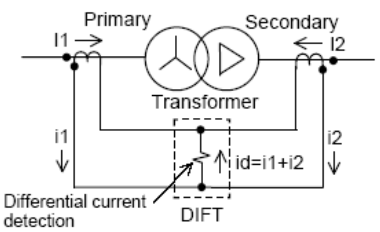


Fig. 1 Current Differential Protection

Longitudinal electromagnetic differential protection is achieved in two variants [2]

- with current relays;
- with differential relays with. Saturation.

If transformers (autotransformers), longitudinal differential protection of some features: inequality offset currents from the ends protected zone, lagged compensation currents, compensating current imbalance, off sensitivity protection against the current shock magnetization.

A current trend in energy is to improve transformer protection using digital monitoring systems. Protective relays based on microprocessors, commonly known as relays numerical scale are used increasingly widely for the protection of power transformers. Numerical relays have many features with adaptive possibilities to optimize the system configuration and performance protection.

II. CURRENT STAGE IN THE FIELD OF NUMERICALS DIFFERENTIAL PROTECTION

Research to achievement of numerical industrial protection started in 1971 at American Electric Power Service Corporation and IBM. One year after the start of the research was first electrical substation computer.

As a first step, most specialists have tried to achieve centralized structure, with one high capacity computer, which combine both functions automatic system functions and facilities protection.

Microprocessors occurrence made this design to be changed, are now made protective structures microprocessor dedicated to each object in the power system. These structures can be found in the upper hierarchical levels, Fig.2.

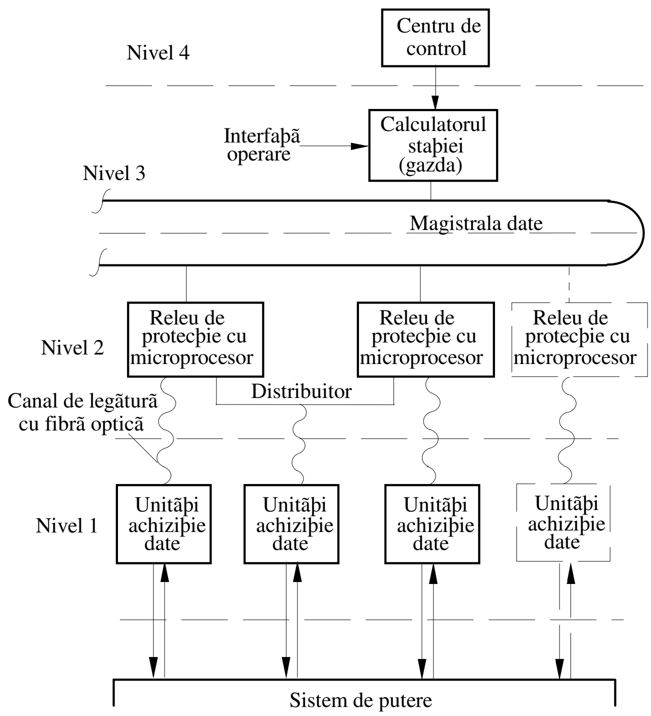


Fig. 2 Architecture numerical structure protection

In the differential protection of power transformers, current trend is to make numerical relays with multiple functions, including protection features and differential (Diff). Show here some examples of numerical differential protection with indication of models that P63x and GRT 100 which are already introduced in the transformer stations of CN Transelectrica SA [3].

P63x numerical differential protection

A prime example of numerical differential protection, with a chart operating in three slopes, P63x is the product of German company ALSHTOM, Fig. 3.

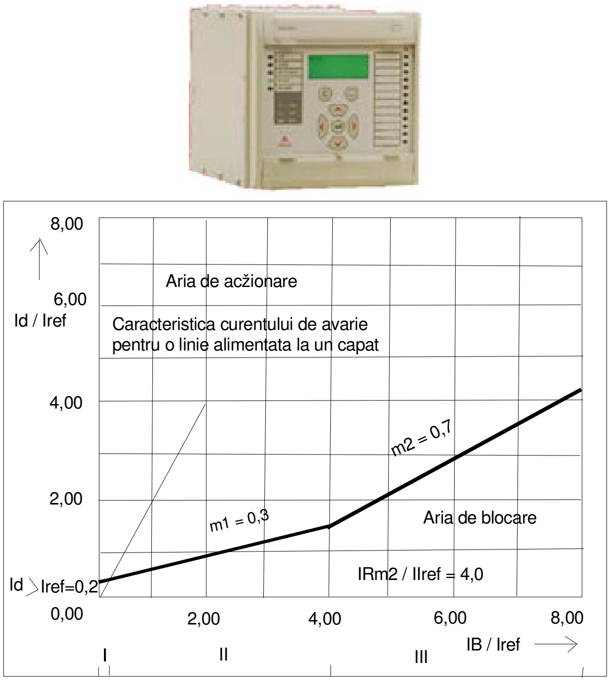


Fig. 3 Protection differential numerical P63x

Differential protective devices P63x have the following main functions:

- three-phase differential protection to protect items with two involution;
- adjusting amplitude and the group of connections;
- filtering current removal sequence for each involution can be disabled;
- three slopes characteristic;
- the limitation of current shock magnetization harmonica with two optional with or without global effects;
- limiting overflux because harmonica 5, can be disabled;
- stabilization- direct care discriminatory saturation;
- differential protection removal (I) (Br: protection against making prohibited ground). (This feature is not available at P631);
- the current maximum protection with independent time (three steps on selective phase measurement system separately for the currents phase currents of the reverse sequence, respectively residual current);
- current maximum protection feature with time-dependent inverse (one step, selective on phase measurement system;
- separately for the phase currents, reverse current sequence and current residual);
- protection against heat overcurrent choice reply heat absolute or relative;
- protection maximum / minimum frequency;
- protection maximum / minimum voltage
- (voltage-time protection);
- limit value monitoring;
- programmable logic.

The user can select individually all the main functions for inclusion in the device configuration or to delete them as they please. With the help of a simple configuration the user can adapt the device for the purpose of protection required. Modular Structure is shown in Fig. 4.

Capacity unit, freely configurable logic can also P63x as to adapt to specific applications [4].

Numerical differential protection with current carrying lines for very high voltage (FIT)

Due to high performance, differential digital protections are not devious or electric air lines. In Fig. 5 is the scheme of principle of a differential line number for a FIT with three terminals

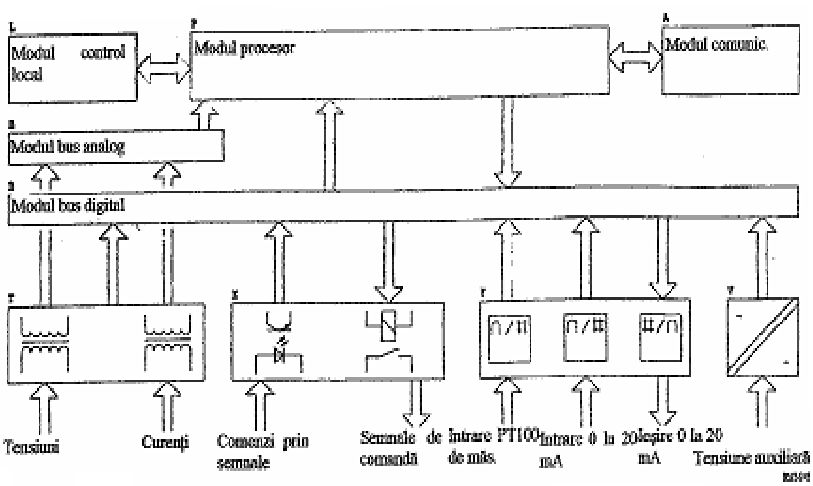


Fig. 4 Modular Structure P63x

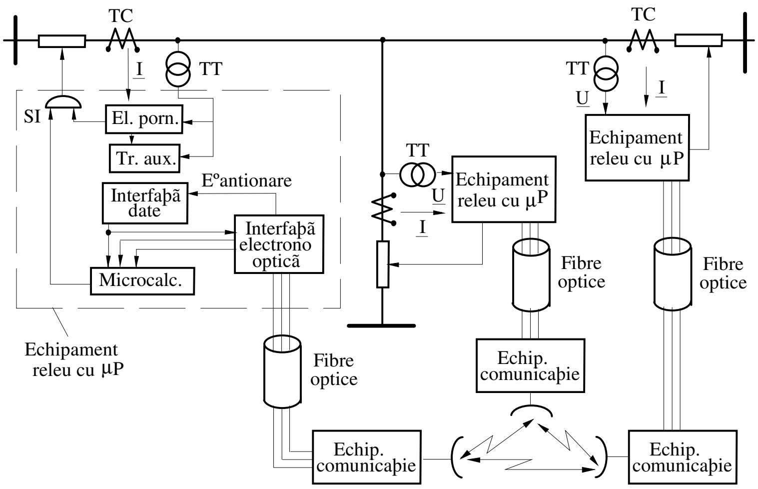


Fig. 5 The principle of numerical differential protection

Method of protection of current carriers is based on the principle that the vector sum of currents of each terminal is ineffective when the transmission line to be protected is as normal and the vector sum is equivalent to the current crash when a damaged transmission line.

Is actually the classical differential protection of transformers of force applied in this case a line FIT [5].

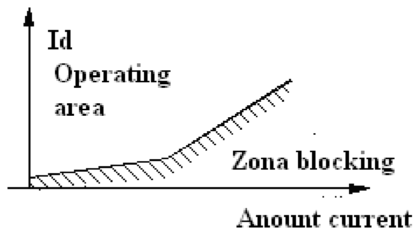


Fig. 6 Double Slop Characteristic

Overall quantity of information transmitted is 54 kb/s. Characteristic performance of the differential protection with current carriers, Fig. 6 is given by equation:

$$|i_A + i_B + i_C| > k\left(|i_A| + |i_B| + |i_C|\right) + k_0, \quad (1)$$

where:

IA, IB, IC - the power of each terminal;

k, k0 – constant.

Vector sum of currents of each terminal has the size of operation, and the sum is the scalar value of maintenance.

In the area of large currents, the ratio has a large value, given that the current transformer errors may grow in this area.

Numerical differential protection GRT 100

GRT 110, product of Toshiba is a numerical transformer protection relay, which can be applied for two-winding or three-winding power transformers, auto- transformers and generator- transformer units.

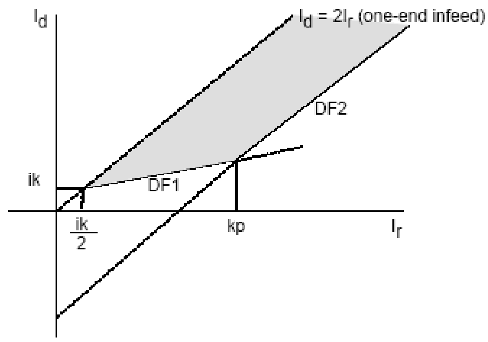


Fig. 7 Numerical differential protection GRT 100

The main transformer differential protection is supported by restricted earth fault, back-up overcurrent, thermal overload, over-excitation and frequency protections. In addition there are standard GR-series features such as metering, data recording and communications.

Matching of CT secondary currents is shown in Fig. 8.

The currents supplied to the differential elements must be matched in phase displacement and amplitude under through-load and through-fault conditions.

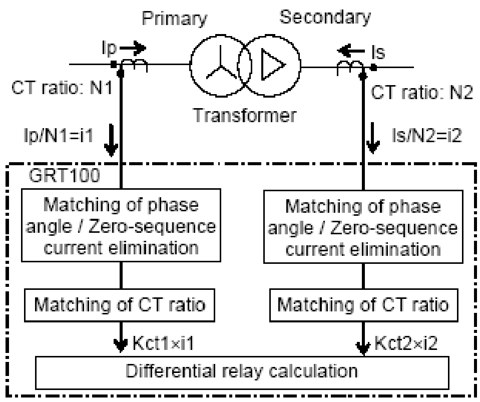


Fig. 8 Maching Method

Generally, it is difficult to completely match the incoming current with the outgoing current for the relay input because the CT ratios at the primary, secondary and tertiary sides of a transformer are not matched in terms of the CT ratio, phase angle and cancelling of zero-sequence current.

GRT100 provides the following matching method.

GRT100 supports selectable two matching methods, α-method (Alpha) and β-method (Beta). The method is selected by the scheme switch [Phase matching].

Phase matching is performed by setting according to the hands of a clock and the transformer connections described in IEC60076-1. For details of the setting, refer to [6].

Numerical differential protection TPT 100

Power transformer protection practices include a variety of protection schemes and philosophies depending on the voltage level and power size.

The most variety used transformers ay 220/400kV are the autotransformers.

The paper [1] presents the protection philosophy and protection function for autotransformers 220/110 kV, 200 kVA. The power transformer protection basic layout is shown in Fig. 9.

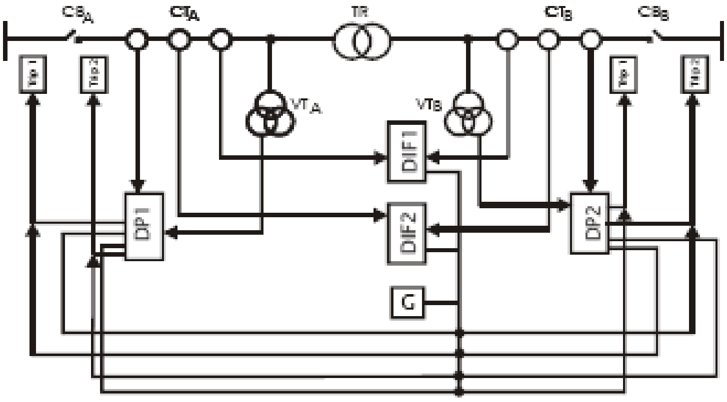


Fig. 9 Power Transformer Protection Layout

The essential requirements associated with such kind of autotransformers are listed below:

- detect and trip for internal tank faults to ground or to alternate phases;
- detect and trip for external tank faults to ground or to alternate phases;
- detect and trip for internal turn-to-turn faults;
- detect and limit for top oil temperature over-rise and hot spot winding temperature.

Principal characteristics of proposed terminal TPT 100, made in Timisoara University, are listed in [7].

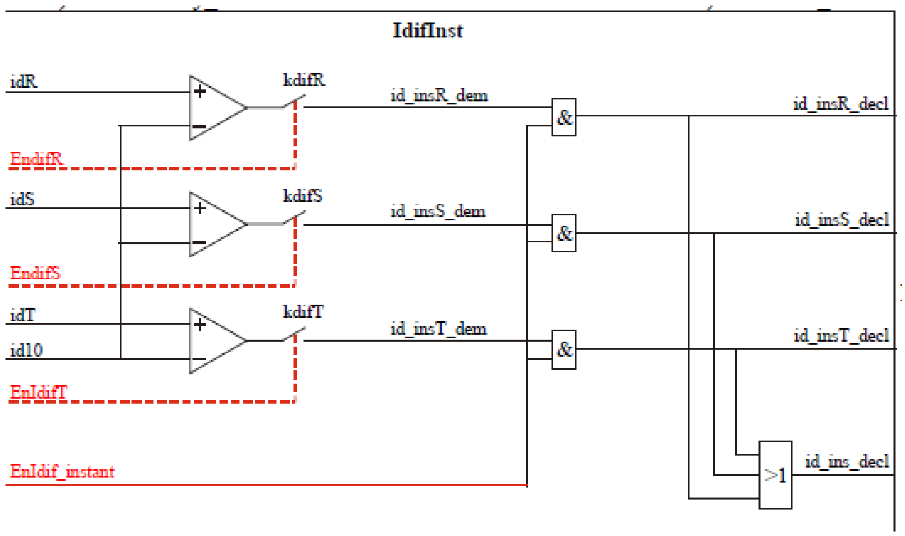


Fig. 10 Logic scheme for instantaneous differential protection

Instantaneous differential protection function is made for high current fault elimination in protected area Fig. 10. This function is analogous with the brake action differential function, except:

- it have no braking action;
- it have no effect at interlocking of magnetization current shock
- it have no effect at extern interlocking.

Magnetization current has negative influence on differential protection functionality, not being able to be compensated. Differential protection function interlocking may be done by two methods:

- by use the magnetization current curve harmonics
- by use the recognition of magnetization current curve specific shape.

Usually, blocking uses two and five harmonics is made by a logical diagram like the one shown in Fig. 11.

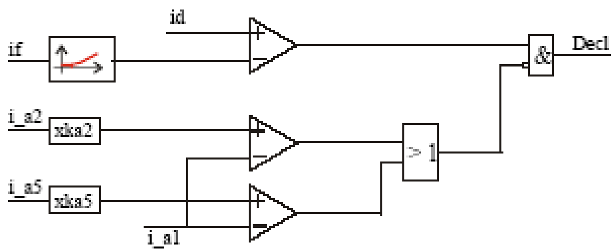


Fig. 11 Principle of upper harmonics blockage

III. CONTRIBUTIONS TO CONSTRUCTION OF NUMERICALS DFFERRENTIAL PROTECTION USING SOFTWARE AND HARDWARE FROM NATIONAL INSTRUMENTS

LabVIEW is made in USA from National Instruments and is differed of other programs throw the following essential aspect: in time the other programmer mediums use languages based on text for created cod lines, LabVIEW use an graphic programmer language at realization a block diagram put into execution then.

LabVIEW programs are called virtual instruments, or Vis, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. LabVIEW contains a comprehensive set of tools for acquiring,, analyzing, displaying, and storing data, as well as tools to help you troubleshoot code your write.

In LabVIEW, your build a user interface, or front panel, with controls indicators. Controls are knobs, push buttons, dials and other input mechanism. Indicators are graphs, LEDs and other output displays. After you build the user interface, you add code using. Vis and structures to control the front panel objects. The block diagram contains this code, Fig. 12.

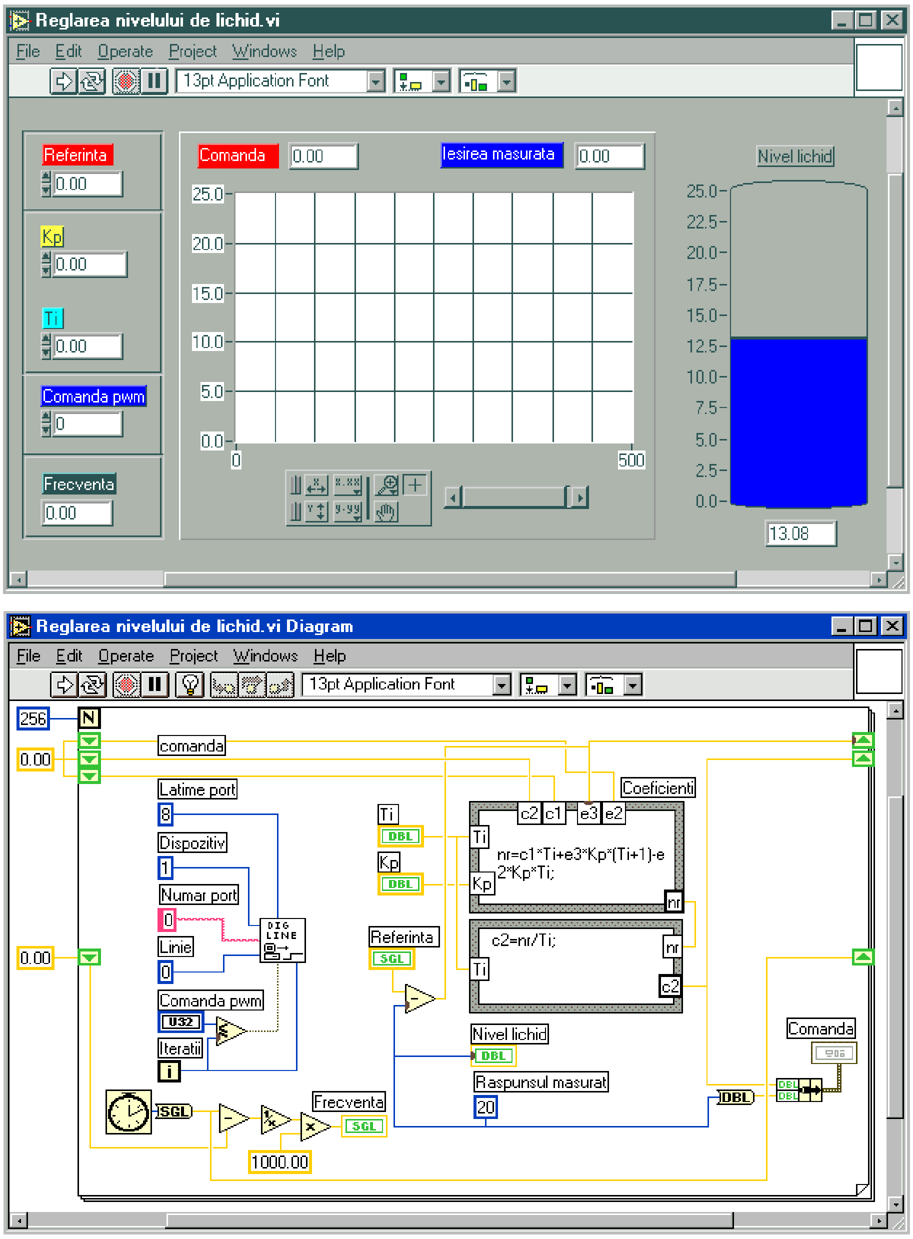


Fig. 12 LabVIEW diagram and frontal panel

We can use LabVIEW to communicate with hardware such as data acquisition, vision and motion control devices, as well as GPIB, XI, VNI, RS 232 AND RS 485 instruments [8]. The National Instruments USB-6008 provides basic data acquisition functionality for applications such as simple data logging, portable measurements, and academic lab experiments. It is affordable for student use and powerful enough for more sophisticated measurement applications, Fig. 13.

Fig. 13 Data Acquisition Device NI USB 6008

- 8 analog inputs at 12 or 14 bits, up to 48 kS/s
- 2 analog outputs at 12 bits, software-timed
- 12 TTL/CMOS digital I/O lines
- 32-bit, 5 MHz counter
- Digital triggering
- Bus-powered.

LEM module used as transducer for electrical sizes of power transformers [9]

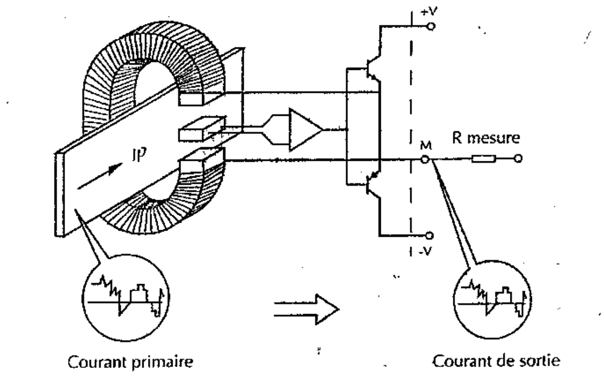
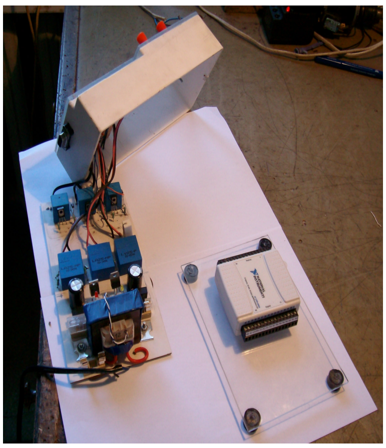


Fig. 14 Module LEM Hall effect

The magnetic field generated by a current measurement is compared with a field created by the secondary winding, which surrounds the probe with a Hall effect associated with an electronic compensation circuit. Current position is the current primary image with reduced number spiral of secondary winding transductor, Fig. 14.

Contributions refer to the experimental numerical differential protection in two variants. The first variant uses programmable logic of automatically Series PT 100 [10]. The second variant use interface with current transducers LEM NP-25 with the Hall effect, the device NI USB-6008 and a PC installed with the LabVIEW program. This second variant of the differential protection with PC (DPPC) is described below.

In Fig. 15 is shown the interface with LEM and double slopes characteristic of DPPC.



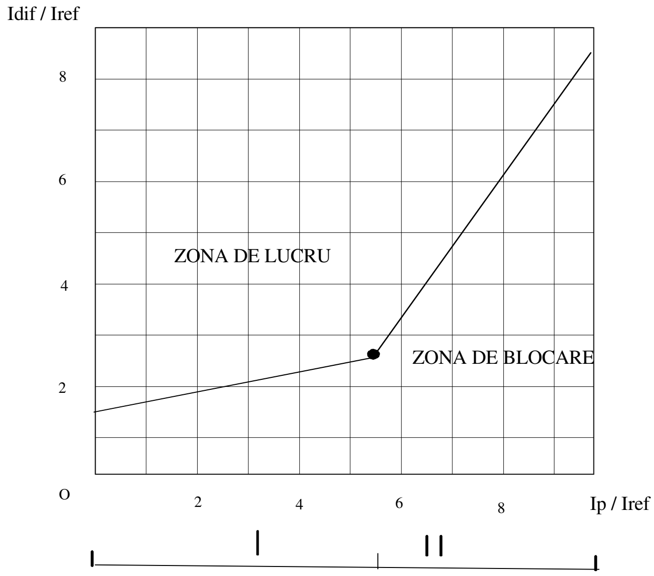


Fig. 15 Differential Protection DPPC

Functions performed with PDPC are:

- phase currents software compensation;
- double slopes characteristic;
- outsensivity protection against the current shock magnetization;
- thermal protection [11];
- protection min / max voltage;
- programmable logic [12].

Phasing compensation is done by software methods, thus eliminating the current differential relay devices in the classics. In the case of transformers with star-triangle connection, currents and IpI, IpII involution of the two have different phase angles between these currents there is a primary phase of 30° or multiples of 30° (for example a transformer connection Y / Δ -- 11difference between the phase currents is 30°, the current party Δ phased after being on the trend in Y). To avoid the abnormal functioning of a classical differential method made connecting the two groups of current transformers in reverse to mayor. The proposed method is illustrated in Fig. 16.

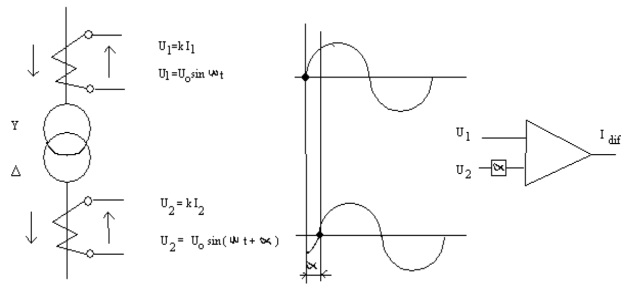


Fig. 16 Principle of compensation

Differential Protection with PC (PDPC) phasing compensation made by methods like using a software procurement NI.DAQ 6008 and a PC installed with the LabVIEW 8.2. Compensation scheme is shown in Fig. 17.

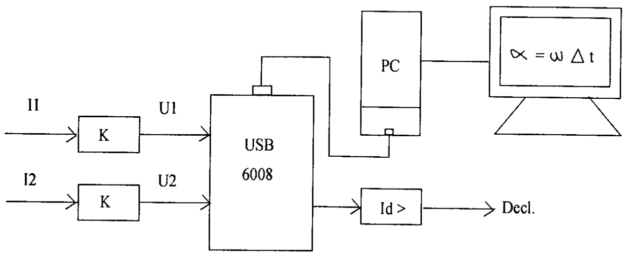


Fig. 17 Phasing Compensation

When two transformers involution overload protection shall be designed on the winding not covered adjustable under load (plotters). PDPC If we used two temperature transducers LM 335Z. Scheme to achieve thermal protection using LabVIEW is presented in Fig. 18.

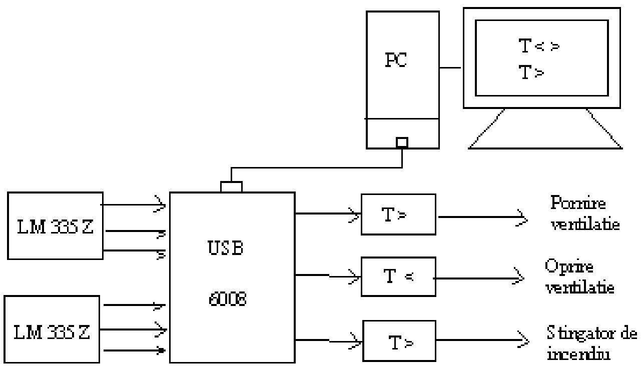


Fig. 18 Heat protection

IV. CONCLUSION

A current trend in energy is to improve transformer protection using digital monitoring systems use more frequently compared to electromechanical relays or static is due to advantages they offer:

- communication networks dedicated to local level and cell level station;
- the communication man-machine offers multiple possibilities ;
- autocontrol function is one of the most important protection for optimizing maintenance;
- high reliability.

However, integration at the same level of protection features multiple command and autocontrol lead to substantial reduction in the volume of the secondary circuits of the station, reducing the probability of occurrence of human errors and improving the electromagnetic compatibility.

Groups of multiple sets of settings offer the possibility of integrating relay in the current station configuration and the energy system. The solution usually used in this case is changing the group settings or by using optoisolated inputs dedicated to this purpose.

Drawbacks are: the need for engineers protectionist very well trained and extremely long time required practical training and testing of new models and prototypes.

A simple calculation reveals us a very interesting: the use of on-line PC computer for monitoring and protection of processing stations is advantageous economically, compared with electromagnetic relays.

Should mention the possibility protection numerical integration in SCADA (Supervisory Control and Data Acquisition) as a general command-surveillance stations transformation.

Advanced digital signal processing techniques and recently introduced Artificial Intelligence (AI) approaches to power system protection provide the means to enhance the classical protection principles and facilitate faster, more secure and dependable protection for power transformers, Fig. 19.

Also it is anticipated that in the near future more measurements will be available to transformer relays owing to both substation integration and novel sensors installed on power transformers. All this will change the practice for power transformer protection. This paper briefly reviews the state of the art, but is primarily devoted to discussion of the new approaches and future directions in digital relaying for power transformers.

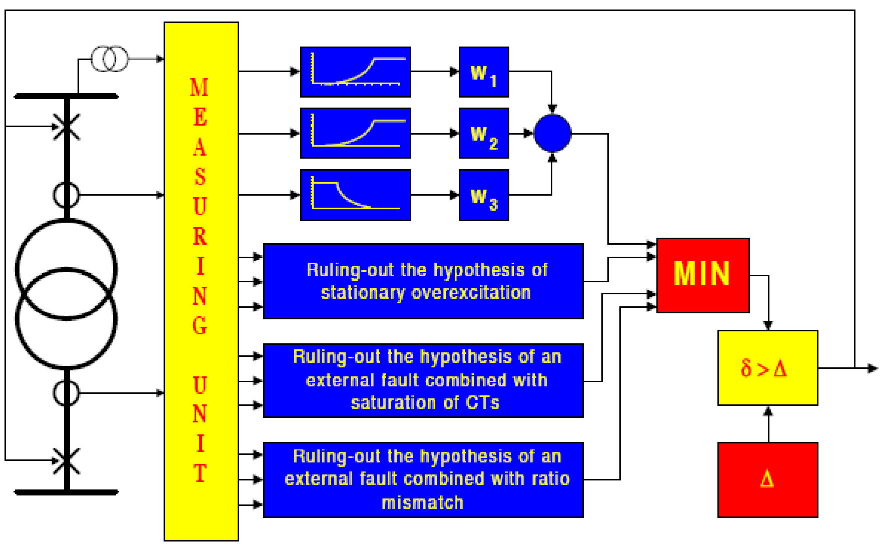


Fig. 19 Blok Diagram of the Fuzzy Logic Differential Relay

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