Considerations about the Development of Protective Devices on the Increase Safety in Exploitation of the Electric Power Transformers

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***Abstract* - Installations and devices of the protection, mounted on transformer, are: oil conservator, gas relays, thermo-siphon filters, air filters, safety valves and thermal image (thermo-copy). Here are some contributions to the development of devices to increase safety in exploitation of power transformers such as gas protection on-line and relay protection for on-load-tap-changers. The constructive principles of gas Buchholz relay (patented in 1921) remained generally unchanged, as with all the past nearly 100 years. In the exploitation of electrical power transformers have been noticed, on the basis of statistics prepared in the USA since 1947, a number of inconveniences. In first place is erroneous operation of lifting-contacts with mercury, in terms of vibrations, as for example disconnection of power transformers through gas protection, in high voltage stations of Romania, at the 1977 earthquake. As a result, in practice showed various models: gas relays with magnetic contacts, gas relays with cups and resort, gas relays with bellows, electronic gas relays and others. These have a correspondent to the versions equipped with a single float that are used as protection for on-load-tap-changers. For this reason, we have studied and protection of on-load-tap-changer, that command disconnecting breakers of the transformer, when current speed of oil through pipe, from tank of the on-load-tap-changer to the oil conservator, exceeds a threshold value. Thus, the capacitor C2 (from the scheme of the gas protection on-line for power transformers), patented individually under the name *Flag to flow velocity*, meets all conditions in order to provide as protection for the on-load-tap-changer. Protections gas integration in SCADA (Supervisory Control and Data Acquisitions) is the last issue addressed before final conclusions.**

Keywords - *power transformer, gas relay, capacitive sensor, data acquisition*

I. Introduction

The main protection against faults, which are normally transformers with powers over 1000 kVA, is gas protection. They are mounted in the pipe between of the transformer tank to conservatory of oil and acting in the case of gas accumulations, oil losses and a high flow of insulating liquid [1]. This protection can be applied only to transformers with oil electro-insulating and with conservatory. She's acting in the case of defects inside the transformer tank (see for example Fig. 1). Under these conditions, electric arc or the heat caused by a short circuit, causing decomposition of the oil and organic materials that enters in the composition of the insulating parts and the consequent is the formation of gases. These, being the mass smaller than the oil, they pick up, moving to conservatory.

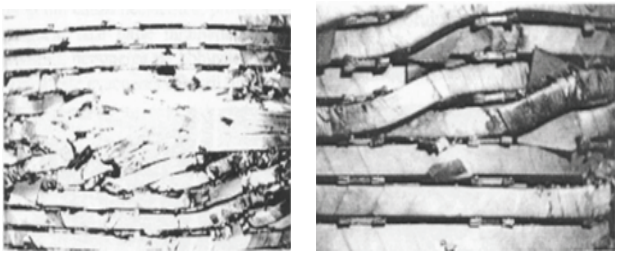

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Fig. 1. Faults of the windings of an electric power transformer because of errors by technology: a) Example of failure due to improper execution of the transpositions; b) Detail of the defect caused by improper execution [2]

In the case of more serious faults, forming gases can be so violent, that the pressure inner, taking birth, can cause and of the oil a movement toward conservative oil.

II. Gas Relays and Protection for Tap Changers

A. Gas Relays

The device which detects the gas formation or violent movements, such as the decrease of the oil level, it is the gas relay, also known as the Buchholz relay (Fig. 2 a). It is mounted in the pipe between of the transformer tank and conservatory, who must have a tilt in the direction of the conservatory of 1°, to ease the eventual transition of the gases to conservatory [3]. In [4] stated the same thing, showing that the slope of the pipe must be 2 – 4% (Fig. 2 b). Basic protection of power transformers with insulation liquid, in case of gas accumulation, is done with relays Buchholz.

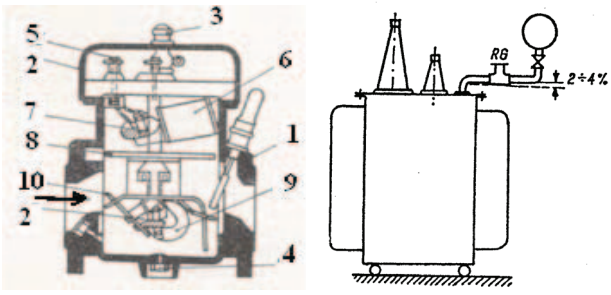

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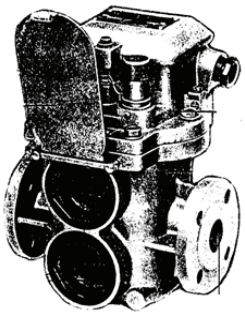
Fig. 2. Gas Relay (Buchholz): a) Principle sheme: 1-case; 2-cover; 3-gas outlet; 4-hole oil; 5-electrical terminal; 6-float higher; 7-contact with mercury; 8-plat separation; 9-float lower; 10-palette for action [6]; b) Installation of gas relay on electric power transformer [4]

The constructive principles of gas Buchholz relay (patented in 1921) remained generally unchanged, as with all the past nearly 100 years. In the exploitation of electrical power transformers have been noticed [15], on the basis of statistics prepared in the USA since 1947, a number of inconveniences. In first place is erroneous operation of lifting-contacts with mercury, in terms of vibrations, as for example disconnection of power transformers through gas protection, in high voltage stations of Romania, at the 1977 earthquake. Today, there is and other variants of the gas relays Buchholz, such as: an electronic gas relay [5]; gas relay AEG (form Germany), with magnetic pills and two floats [6]; gas relay RGZ-66 (from Rush), with two cups and resorts [6]. The main products in this category are equipped with one or two floats and are connected by flanged or threaded (type BF, AG, AF, BG, etc.).

If the gases are inflammable, colorless, odorless and result as the processor remove air stuck inside, after filling the tank with oil. A whitish, non-flammable gas with a pungent is produced by damage to the insulating materials (paper, insulation textiles etc.). A yellow, flammable gas, indicate damage to wooden parts. A dark gray or black and slightly flammable looks like there was a flashover in oil or excessive overheating, accompanied by its decomposition. Gas gathering, to investigate chemical and physical properties, is made by means of a test tube, the exhaust valve of gas relay.

Operation of gas relay, manufactured in Germany (Fig. 3 a), is similar with Buchholz relay. The difference is that in place of contact with mercury, it uses encapsulated contacts with magnetic pill.



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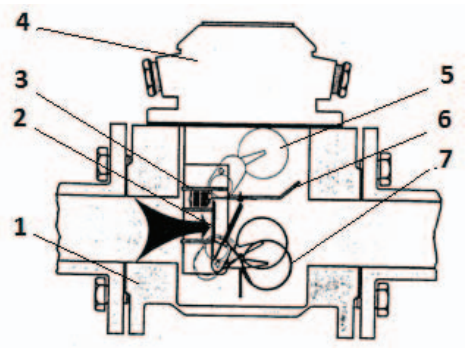

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Fig. 3.Gas relay manufactured in Germany: a) Overview: b) Principle scheme: 1-cover; 2- flap, driven by the wave of oil; 3-permanent magnet; 4-terminal box has an earthing contact and the electrical connectors; 5-float and switching system in the upper part; 6-mobile plate for changing the position of the magnet to adjust the relay's sensitivity to oil wave 7-float and switching system at the bottom part [9]

In Fig. 3 b is presented scheme of principle: the inside of cover 1 is a flap 2, which moves to the wave oil, causing the descent of the float 7 and closing encapsulated contacts from the bottom part of gas relay, which transmits a signal of disconnection to the breakers of the transformer. A furniture board 6, allows changing position of the permanent magnet, offering thus the possibility to regulate the actuation threshold to the wave oil. The slow accumulations of gas down the float 5 and close the encapsulated contacts at the upper part of gas relay, through which pass a warning signal. The terminal box 4 has a contact to the earth and the electrical connectors.

B. Relay Protection for On-Load-Tap-Changers

Generally, at the gas relays with two floats correspond the versions equipped with a single float, that are used as protection for on-load-tap-changers. For this reason, we have studied and protection of on-load-tap-changer, that command disconnecting breakers of the transformer, when current speed of oil through pipe, from tank of the on-load-tap-changer to the oil conservatory, exceeds a threshold value. In Fig. 4 is shown installation of relay protection on a transformer with on-load-tap-changer.

The free float category relays can be considered the type shown in Fig. 5 a and literature known as “pressure relay” [4].

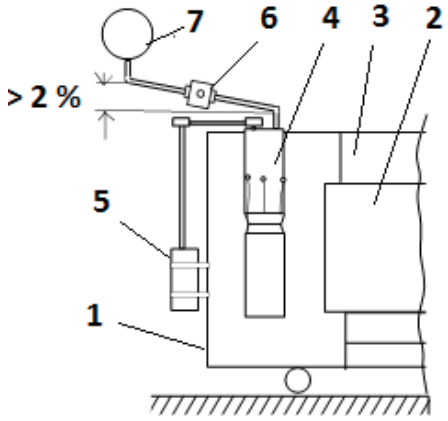
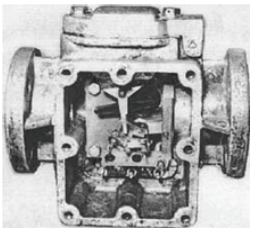


Fig. 4.Installation of relay protection for tap changer: 1-Tank of transformer; 2-winding: 3-magnetic core; 4-on-load-tap-changer; 5-mechanism action for on-load-tap-changer; 6-relay protection; 7-oil conservator



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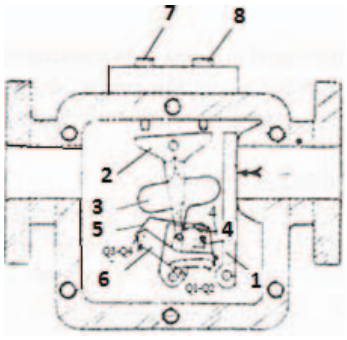

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Fig. 5. Relay protection known as “pressure relay”, contacts with mercury for tap changers: a) Overview; b) Principle scheme: 1 - range of action; 2, 3, 4 – leverages for transmitting actuation force; 5 – elastic spring; 6 - tilt switch; Q1-Q2 and Q3-Q4 - contacts with mercury; 7, 8 - bolts fixing [4]

Relay is mounted on the pipe connecting the vat of the tap changer (for setting the voltage transformer under load) and signals the formation of the violence wave (see Fig. 5 b), caused by gas and oil: the emergence of arcs from switching operation due to increased wear contacts, the emergence of the phenomenon of rebound in contact, when combustion occurs. Vat hole communicating with the switch is to obstruct a wide 1, related to tilt format levers 2, 3, 4 and spring 5. Under the gas flow occurs tilting system of levers in a position to another, which causes mercury tilt switch tilt 6 (V-shaped), jointly mounted by the lever 3, interrupting the contact Q1-Q2 and realizing the contact Q3-Q4. The leverage of the relay described may be made in either of the two stable positions by the action of bolts 7 and 8, mounted on relay case.

Another relay protection for tap changers [16] has contacts with magnetic pill encapsulated in tube. It is mounted on the pipe connecting the vat of tap changer (for setting the voltage transformer under load) to conservatory. The relay for tap changers, also named protection relay for tap changers or oil flow relay, is a monitoring relay for oil-insulated tap changers. It protects the tap changer and the transformer from damage. On response the monitoring relay will generate a signal disconnecting immediately the tap changer and the transformer from the source of supply.

To check the switching system for proper function, the casing is provided with inspection glasses (see Fig. 6 a), arranged opposite each other, protected by hinged lids. In the Fig. 6 b it's shown the principle of working method of the dumping. The cover 1, is a casting of light alloy and is provided with a paint coat. Terminal box 2, covered by a cap nut, are arranged above the cover. The terminal box has an earth contact and the electrical connectors. Is safe to touch and protected against pollution.

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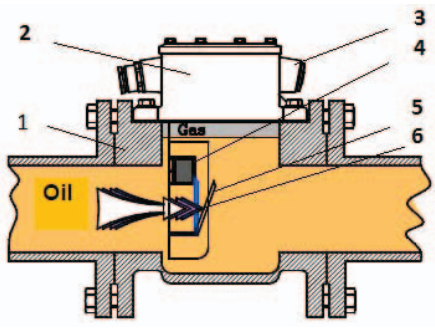

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Fig. 6. Relay protection, contacts with magnetic pill encapsulated in tube, for tap changers: a) Overview; b) Principle of working method of the dumping: 1-cover; 2-terminal box has an earthing contact and the electrical connectors; 3-cable gland; 4-permanent magnet; 5-magnet contact tube; 6-damper [12]

The cable is to be brought in the terminal box through the cable gland 3. The switching system consists of the following components: permanent magnets 4, magnet contact tube 5 and damper 6. The damper 6 is retained in its normal and response positions by permanent magnets 4. Via a link the permanent magnet is firmly connected with the damper and initiates the contact-making process of the magnet contact tube 5 at a certain oil flow.

We have seen that these relays protection for tap changers have a correspondence with the gas relays, i.e. they are variants with a single float to the relay gas by removing the warning system.

For this reason, we have studied and protection of on-load-tap-changer, that command disconnecting breakers of the transformer, when current speed of oil through pipe, from tank of the on-load-tap-changer to the oil conservator, exceeds a threshold value. Thus, the capacitor C2 shown in Fig. 10, patented individually under the name *Flag to flow velocity*, meets all conditions in order to provide as protection for the on-load-tap-changer. Just like the gas relays, which I've studied it represents the variant, with a single capacitor, of the protection gas on-line for power transformers (see the Fig. 8).

III. The Gas Protection On-Line

In this chapter, we will be treated on implementation for on-line gas protection for power transformers, with all the consequences that coming from this solution. The need for a such approaches, results from the trend of modernization of the all protections in the energy systems [7] and their integration into a single centralized system, according to the concept called SCADA (Supervisory Control and Data Acquisition). Realization of the on-line gas protection and its integration in SCADA is a method to increase safety in exploitation of the electric power transformers.

The novelty of the solution [8], lies in the use of capacitive sensors, to replace the ball floats and mercury contacts moving from side to side of classical relays gas or the floats and magnetic pills in the newer versions. According to terminology presented in the literature, the proposed solution is implemented such as in Fig. 8:

- the switching system signaling, which occupies the upper of the classic relay gas (see Fig. 2 – nr.6 and 7), is replaced with the capacitor C1, which gives the impulse switching when is low oil level, or the accumulation of gases;

- the switching system trigger, which occupies the lower of the classic relay gas (see Fig. 2 – nr.9 and 10), is replaced by a capacitor C2, which gives the impulse trigger when a defect caused a wave of oil, coming from the transformer tank to the conservatory, whose speed exceeds the permissible speed, corresponding of the trigger level admitted, established on the graduated palette P;

- the gas collection system, that current is a manual technology, there are some kits for the collection of gases and oil, which means the movement on the ground of the electricians, existing possibility to compromise this samples (see Fig. 7), is replaced with the gas Analyser Ag, which is mounted in direct connection with a gas Chromatograph CG, provides information in real time regarding the structure of the content gases dissolved in oil.

Fig. 7. Gas sampling devices [9]

The new system proposes chromatographic analysis (on-line) of the gases accumulated inside the relay, through the circuit: *gas Analyzer - gas Chromatograph - computer PC*, which provides the ability making decision in real time, in relation to maintenance the transformer in operation, if the result of the chromatography is inadequate.

From the board data acquisition PAD, we have the following impulses: *Signaling lower oil level, Gas Chromatography, Open circuit breaker*. To these are added the action orders to the resorts of the two electro-valves, providing the access of the gases in Analyzer Ag, respectively their escape in atmosphere.

Gas relay for power transformers, Fig. 8, according to the invention [8], is mounted on the pipe between of the electric power transformer TR to the conservatory of oil, through a special tube T, which allows removal and replacement without draining the oil conservatory.

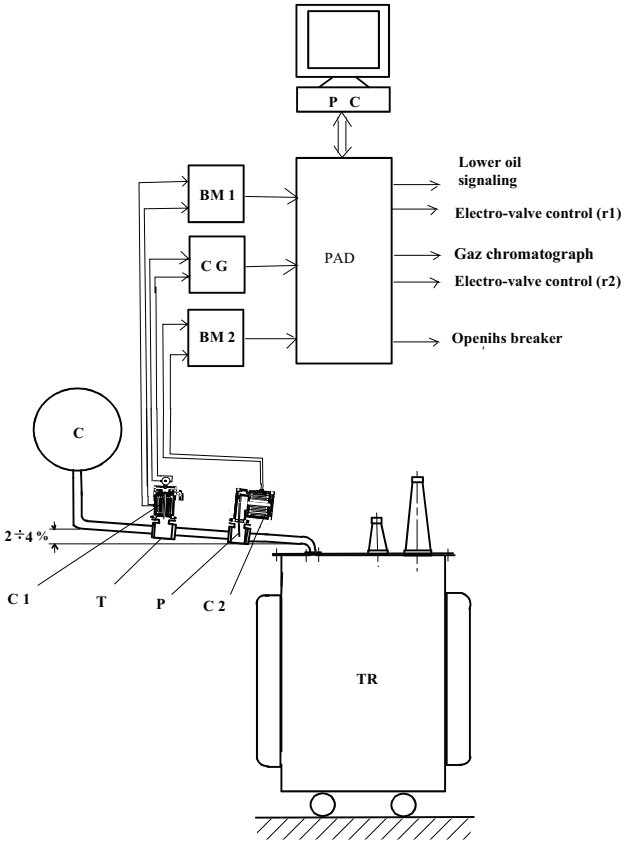


Fig. 8.Schematic diagram of the gas protection on-line, for power transformers: TR-power transformers; C-conservative oil; P-palette for action at the speed of the oil; T- especially tube connection; C1-capacitor; C2-capacitor; BM1-block measurements; BM2-block measurements; GC-gaz chromatograph; PAD-board data acquisition; PC-computer control, located in the control room of transformer station [8]

A. Level Indicator

Level indicator [10], is a type of capacitive sensor. The capacitor C1 (see Fig. 9 a), is a plan condenser, placed in vertical position, design fixed, his capacity is variable, depending on the level of the oil in its interior, being built so: a housing 1, which contains a set of metal plates 2, mounted alternately on an electro-insulating support 3 and an electro-insulating support 4, supports fixed on the electro-insulating axis 5, electrical connection to block measurements BM1 making it through electrical terminals 6 and at the top of him having a cover of access 7, in which is included a gas Analyzer Ag, connected to a chromatograph GC, which presents a written report about the chemical composition of the gases emitted. Access to the gas Analyzer Ag is done through a resort r1 of an electro-valve and by the action resort's r2 of another electro-valve, the gases are discharged into the atmosphere through a nozzle exhaust gas 8.

In Fig.9 b is showed the action characteristic of the indicator level, make experimentally at University "Stefan cel Mare" Suceava, using in test an electro-insulating oil at that, dielectric permittivity ε is 2,2 at 20 ° C and 50 Hz.

B. Flag to Flow Velocity

The flag for the flow velocity [11] is a type of capacitive sensor. The capacitor C2 (see Fig. 10), is a plan condenser, design variable, similar to previously described, except that it is placed horizontally and electro-insulating support 4, moves by the axis 5, due to the action of a palette 7, placed inside the tube for the reason to signal the speed of flow of the oil, in the case of violent movements of the oil caused because of major internal faults.

Electronic measurement of the capacity C2, is done in the block measurements BM2. A data acquisition board PAD, connected to a central computer PC, collects from the process the three parameters supervised, as follows: the level of the oil in the transformer via block measurements BM1, chemical composition of the emanated gases via the gas chromatograph CG and the speed of movement of the oil and gas from tank to conservative via block measurements BM2.

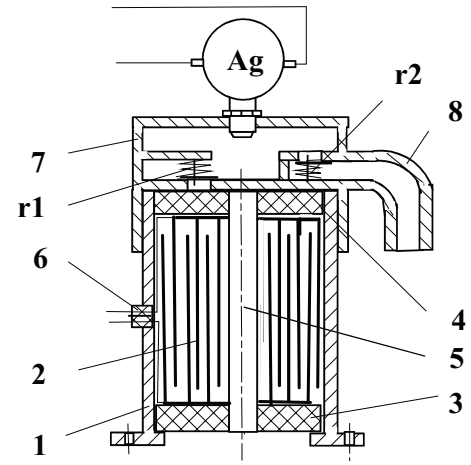
IV. Solutions to Introduce Gas Relays in SCADA (Supervisory Control And Data Acquisitions)

Present below some aspects of the tele-mechanics management that are necessary for integration in SCADA. The main tasks of a system for operative management of electrical networks can be grouped in the following categories:

a) General information of dispatcher about the topology and status of the power system driven, through human-machine interfaces;

b) Alarm in case of certain events take place, which must be taken into account immediately;

c) Information for post fault analysis, by retaining a history of events produced in a given period of time, accompanied by the time of their occurrence [12].



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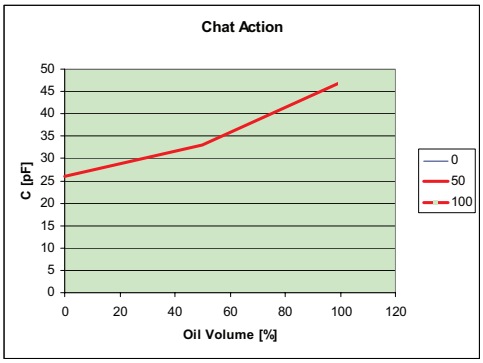

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Fig. 9.(Explanation to Fig.8): a) Level indicator with gas analyzer: 1-housing; 2-set of metal plates; 3, 4-insulating supports; 5-axis electro insulating; 6-electrical terminals; 7-cover of access; Ag -gas analyzer; r1 and r2 – elassic springs for electro valves; 8 - nozzle exhaust gas; b) Action characteristic of the indicator level in electro-insulating oil [10]

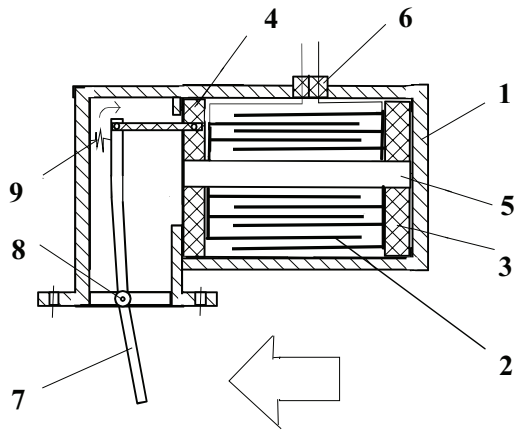


Fig. 10. (Explanation to fig.8): a) Flag to flow velocity:1-housing; 2-metal plates; 3-eloctro insulating support fixed; 4- electro insulating support mobile; 5-axis electro insulating; 6-electrical terminal; 7-palette for action; 8-axis; 9-elestic spring [11]

Gas relay protection scheme, Fig. 11 a is provided with relay RI-2 with auto-retention output for providing a trigger pulse and extended by manual release button B, as the defect in the transformer windings [13].

In a processing station, on the cell of transformer 110/20 kV, meet the following basic groups of signals (those relating to protection of gas, were highlighted in the text), which must be considered when desirable remote management of the process:

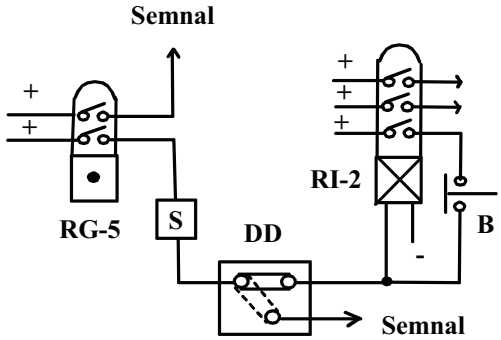
• *Protective Signaling* for switcher 110 kV (plug / triggered), the separator bar 110 kV (closed / open), the separator 110 kV transformer terminals (closed / open); Knives earth (closed / open) MT switch (plug / triggered); separator MT Bar (closed / open); separator transformer terminals MT (closed/ open), plot (min / max);

• *Alarm Signaling*. Fault switch, low pressure at MOP (Mechanism Oleo-Pneumatic), burning fuses control and signaling, **worked gas protection**, worked differential protection, worked maximum protection on 110 kV, worked maximum protection on 20 kV; worked PRBMT, **gas signaling**, signaling overload, signaling over temperature, abnormal oil level;

• *Measures*: active power, reactive power;

• *Electric energy meter*: active and reactive energy;

• *Orders*: Operate / release switch 110 kV; Operate the trigger switch MT; closing / opening separator bar 110 kV; closing / opening separator 110 kV transformer; closing / opening bars separating MT; opening / closing separator MT transformer.



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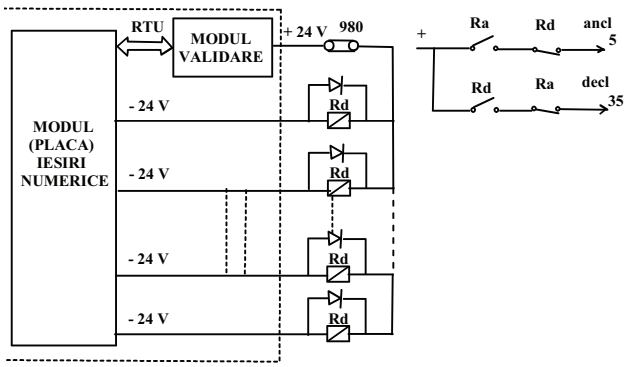

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Fig. 11. Solutions to introduce the gas relays in SCADA (Supervisory Control and Data Acquisition): a) Electrical scheme of the classic gas protection [13]; b) The implementation of the scheme remotes via the validation module [6]

Module validation, Fig. 11 b supports remote execution (validate command), if conditions are met:

• there are no other commands;

• there is energy supply relays.

On-line monitoring of power transformers [14] may include in the future and protection of gas, taking into account the issues presented in this chapter.

V. CONCLUSIONS

Currently, studies in this paper were developed in the following areas:

- improving the operation of the moving contacts with mercury under vibration;

- new solutions for switching systems with safer for vibration and seismic conditions;

- increased sensitivity of gas relays for use in case of small power transformers and special purpose;

- the achievement of relays with three distinct functions: signaling the slow accumulation of gas, trigger violence defect, if accompanied by the formation of an oil wave from the oil tank to the conservatory, opening breaker as a result of oil level leaks;

- achievement on-line gas protection (see Fig. 8, Fig. 9 and Fig. 10) and integration in SCADA (Supervisory Control And Data Acquisition) (see Fig. 11 a and Fig. 11 b).

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