MÉTODOS CLÁSSICOS PARA PREVER O DESEMPENHO DE RELÉ BUCHHOLZ DANDO OS FENÔMENOS DE FALHA INCIPIENTE NO TRANSFORMADOR IMERSO DE ÓLEO**CLASSICAL METHODS TO PREDICT THE PERFORMANCE OF BUCHHOLZ RELAY BY GIVING THE PHENOMENA OF INCIPIENT FAULT INTO THE OIL IMMERSSED TRANSFORMER****METODE KLASIK UNTUK PREDIKSI KINERJA RELAI BUCHHOLZ DENGAN PEMBERIAN FENOMENA GANGGUAN INCIPIENT KE DALAM TRANSFORMATOR DAYA RENDAMAN MINYAK**GOERITNO, Arief^{1*}; NUGRAHA, Irwan²; BAKTI, Prayoga³¹ Bogor Ibn Khaldun University, Faculty of Engineering and Science, Electrical Engineering Study Program, Indonesia.² Sahabat Sampoerna Company; Credit Analyst, Cimanggis, Depok, West Java, Indonesia.³ Research Center for Testing Technology, Indonesian Institute of Science, Puspiptek Region, Indonesia.

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RESUMO

Este trabalho explica os métodos clássicos para a previsão do desempenho do relé Buchholz. Os métodos tradicionais usam simulações, dando um fenômeno de falha incipiente no transformador imerso em óleo. O relé Buchholz é um tipo de relé mecânico cujo mecanismo de operação é influenciado pelo óleo e o gás no tanque do transformador tendem a se mover para o tanque de expansão através da tubulação de interconexão. Este dispositivo é um componente crítico que está integrado na filosofia de proteção do transformador imerso em óleo. Um simulador baseado em circuito eletrônico que é integrado com um painel de controle de operação do disjuntor foi escolhido como um meio para criar condições durante o alarme ou desarme. A medição de desempenho fornece condições de falha simuladas para configuração de alarme e desarme. Fornecimento de simulação de falhas na forma de pressionar um botão uma vez para simular a existência de uma condição de alarme. Nessa condição, o painel de controle dos disjuntores não funciona, mas sim o apontamento de um sinal de alarme. Com base nisso, a sirene soa e a falha de verificação da condição ainda é normal ou "sem bloqueio". Fornecendo pressão total como uma forma de simulação para condições de disparo no relé Buchholz, o painel de controle designa a condição dos dois CBs (lado de 150 kV e lado de 20 kV) abertos, e a designação do sinal de alarme também ocorre com o som da campainha. Portanto, o status da verificação torna-se "bloqueio". O relé Buchholz serve para detectar a presença do gás oriundo do aquecimento local ou picos de pressão no óleo do transformador. Depois de fornecer todas as condições, o desempenho do relé Buchholz é conhecido.

Palavras-chave: alarme e disparo; detectar a presença de gás; simulação de condições reais.

ABSTRACT

This work explains the classical methods for predicting the performance of the Buchholz relay. The traditional methods use the simulation by giving a phenomenon of incipient fault into the oil-immersed transformer. The Buchholz relay is a type of mechanical relay whose operating mechanism is influenced by oil and gas in the transformer tank tend to move into the expansion tank through the interconnecting piping. This device is a critical component that is integrated into the oil-immersed transformer protection philosophy. An electronic circuit-based simulator that is integrated with a circuit breaker operation control panel was chosen as a means for creating conditions during alarm or trip. The performance measurement provides simulated fault conditions for setting on alarm and trip. The provision of faults simulation in the form of pressing a push-button one time to simulate the existence of an alarm condition. In that condition, the CBs control panel does not operate, but the appointment of an alarm signal. Based on that, the Buzzer sounds and the status check trip is

still normal or "no lock-out". Giving full pressure as a form of simulation for trip conditions on the Buchholz relay, the control panel designates the condition of the two CBs (side of 150 kV and 20 kV side) open, and the alarm signal designation also occurs with Buzzer sounding. Hence, the check trip status becomes "lock-out". The Buchholz relay serves to detect the presence of gas caused by local heating or pressure surges in the transformer oil. After giving all of the conditions, the Buchholz relay performance is known.

Keywords: *alarm and trip; detect the presence of gas; simulation of real conditions.*

ABSTRAK

Makalah ini berisi penjelasan metode klasik untuk prediksi kinerja relai Buchholz. Metode tradisional digunakan untuk simulasi dengan pemberian fenomena gangguan incipient ke dalam transformator rendaman minyak. Relai Buchholz merupakan relai tipe mekanis dengan mekanisme pengoperasiannya dipengaruhi oleh minyak dan gas di dalam tangki transformator yang cenderung bergerak menuju tangki ekspansi melalui pipa penghubung. Peralatan ini merupakan komponen penting pada filosofi proteksi terhadap transformator rendaman minyak yang diintegrasikan ke dalamnya. Simulator berbasis rangkaian elektronika diintegrasikan ke panel kontrol pengoperasian pemutus tenaga telah dipilih sebagai sarana untuk penciptaan kondisi-kondisi alarm atau trip. Pengukuran kinerja berupa penyediaan simulasi gangguan untuk penyetelan kondisi alarm dan trip. Pemberian simulasi gangguan melalui penekanan tombol satu kali untuk pensimulasian keberadaan kondisi alarm. Dalam kondisi tersebut, panel kontrol untuk pengoperasian pemutus tenaga tidak beroperasi, melainkan hanya penunjukan sinyal alarm. Berdasarkan hal itu, Buzzer berbunyi dan status pemeriksaan trip masih normal atau "no lock-out". Pemberian tekanan pada tombol tekan secara penuh dan berlangsung lama sebagai bentuk simulasi kondisi trip pada relai Buchholz, panel kontrol dengan penunjukan kondisi dua pemutus tenaga (sisi 50 kV and sisi 20 kV) terbuka, dan penunjukan sinyal alarm juga terjadi melalui Buzzer berdering. Sehingga, status pemeriksaan trip menjadi "lock-out". Relai Buchholz dengan fungsi untuk pendeteksian keberadaan gas akibat pemanasan setempat atau lonjakan tekanan pada minyak transformator. Setelah pemberian semua kondisi tersebut, kinerja relai Buchholz diketahui.

Kata-kata kunci: *alarm dan trip; deteksi keberadaan gas; simulasi kondisi nyata.*

1. INTRODUCTION:

The oil-immersed power transformer in each substation plays a crucial role, so it is said to be the vital apparatus of the connection between the transmission line and distribution network. The oil-insulated power transformer's role has not changed over the last decades (Godina *et al.*, 2015). Supporting equipment as an inseparable part of the power transformer is the proper adjustment of the protection relay, so there is no sympathetic phenomenon (Goeritno and Saidah, 2014) and reliable performance of the circuit breaker (Goeritno and Rasiman, 2017; Goeritno, 2020a).

Guided by the IEC 60076-1 standard, it is said that the power transformer is a static electrical apparatus with two or more windings by electromagnetic induction process, changing the voltage and current in alternating current system into other values which are usually of different values and at the same frequency value to transmit electric power (IEC 60076-1:2011, 2011: 7; Gajic, 2013: 21). The classes for power transformers range from distribution voltages of 2.5 kV to extra high voltages up to 765 kV (Choi,

2014). The power transformers are being operated beyond their designed lifetime (Energetic Incorporated, 2015: 3).

Power transformers have been grouped into three market segments based on power size ranges (Sim and Digby, 2002: 2; Choi, 2014), i.e. (i) small power transformers of 500 to 7,500 kVA, (ii) medium power transformers with the capacity start of from 7,500 kVA to 100 MVA, and (iii) large power transformers (LPT) with capacity is greater than 100 MVA. The presence of transformer oil in the power transformers of oil-immersed type with a capacity of 500 kVA or more (Sim and Digby, 2002: 2; HRTSG, 2005) has been equipped with a conservator tank to anticipate the expansion of oil from the main tank of the power transformer through the connecting pipe.

Faults in power transformers are divided into two types, namely external and internal faults (IEEE Std C37.91-2008, 2008: 8). External faults, including overvoltage, over fluxing, less frequency, and short-circuit on outside of the power transformer (Mohammadpour and Dashti, 2011: 741; Joshi *et al.*, 2012: 77). Internal faults on the power transformer is an event with a

probability ranging from 70% to 80% (Mohammadpour and Dashti, 2011: 741; Joshi *et al.*, 2012: 77) which are divided into two types of faults, namely (i) initial or incipient faults and (ii) short-circuit faults that occur on inside of the power transformer (IEEE Std C37.91-2008, 2008: 8; Wang, 2002: 500; Thangavelan, 2014: 2).

Initial faults include: I) the presence of arcs, II) presence of faults in the cooling system, or III) the existence of circulating currents in parallel operated transformers. The three faults included in the initial faults are the cause of the presence of local heating, but they do not affect the overall transformer temperature (Mishra *et al.*, 2013: 61). These faults cannot be detected from the connection of the transformer windings because the value and balance of currents and voltages that occur are not much different from the conditions when power transformer under normal conditions (Joshi *et al.*, 2012: 77-78).

Short circuit on windings that potentially occurs locally and shock pressure arises in the oil transformer, thus producing flammable gas that is flowed to the conservation tank through connecting pipes and Buchholz relay (Buchholz, 1927), can be called as a gas detector relay (HRTSG, 2005; Hartman, 2018). Although the developing fault is a form of minor detect, it can have a significant impact and be able to cause more severe damage; if not detected immediately. Short-circuit fault is a fault due to the existence of short-circuiting that can be detected; because it is the cause of the presence of abnormal currents and voltages or unbalanced loads (Lin *et al.*, 2015: 3).

Guarantees for protection relays that operate with high reliability, the tuning of the Buchholz relay must be precise so that any faults that may arise can be overcome. Installation of the Buchholz relay as a mechanical safety against power transformers from the faults of gases and oil pressure in the power transformer tank (HRTSG, 2005). This relay is not responsive to external forces. There is no servicing required throughout the function. Guided by these descriptions, then set two research objectives in the form of predicting the performance of the Buchholz relay for alarm and trip conditions. The schematic diagram of the complete structure of the oil-immersed power transformer is shown in Figure 1.

1.1. LITERATURE REVIEW:

The phenomena of switching and protecting are the two phenomenally terminology

in the electrical power system (Samonto *et al.*, 2016: 29). There are amount of components of transmission and distribution, include power transformers, cables and conductors, protection devices, and other equipment, which cannot be separated from the switching and protecting phenomena. The ability of the electrical power system in the supplying for the need of loads as a determinant of the reliability of the system, so always strived to generate the electrical power that equals the demand on the load sides and the transmission-related losses for any time condition (Goeritno, 2020b: 293).

The power transformers are essential to the transmission and distribution of electricity efficiently and reliably (Energetic Incorporated, 2015: 2). Today, the basic physical principle of power transformers is still as it was 130 years ago, but the density of energy, range of efficiency, costs of the product, their weight, and dimensions have dramatically improved. The most important function of the power transformer is transforming voltage levels, stepping them up for long-distance transmission from a power plant, and stepping them down for distribution to consumers (Energetic Incorporated, 2015: 3).

The power transformers are large, box-shaped structures connected to multiple wires and are usually the largest single item in a substation. The power transformer is usually located on one side of a substation, and the connection to switchgear is by bare conductors. Linkage with the large quantity of oil, it is essential to take precautions against fire hazards. Hence, a transformer is usually located around a sump used to collect excess oil. When oil-insulated transformers are located indoors, because of fire hazard, it is often necessary to isolate these transformers in a fireproof vault (HRTSG, 2005).

Power transformer comes in all shapes and sizes to the mammoth Extra High Voltage (EHV) power transformers that weigh several metric tones and occupy large areas (Paithankar and Bhide, 2010: 77). The power transformers are being operated beyond their lifetime, although they do not match the design results. For instance, approximately 70% of transformers are over 25 years old on their operation, while their useful life is estimated only 20 years (Energetic Incorporated, 2015: 3). A variety of faults are often in the power transformers and the most common being the winding to core faults, because of the weakening of insulation. Phase faults inside the transformer are rare (Paithankar and Bhide, 2010: 77).

Physical properties of transformer oil, including (a) thermal conductivity, (b) specific heat, (c) volume expansion coefficient, (d) density, (e) viscosity, (f) pour point, (g) solubility of other substances, (h) vapor pressure, (i) fire resistance, and (j) pollutants (contaminants) (Myers *et al.*, 1981: 158-161; HTRSG, 2005). Thermal conductivity, specific heat, and viscosity as a determinant of the rate of heat dissipation from electrical equipment to outside the tank. These characteristics are for determining the type of cooling that a power transformer needed. Viscosity and pour point also affect the mechanism of heat dissipation. The volume expansion coefficient, fire resistance, interface stress, and dissolution power of the pollutants are also important enough to determine the free space required in the transformer and conservator tank, where it is estimated for all spaces that tend to increase in temperature (Myers *et al.*, 1981: 158-161; HRTSG, 2005).

Excerpts from C. Russel Mason on his book title "The Art and Science of Protective Relays" (Mason, 1956: 3); that the function of protective relaying is to cause the prompt removal from service of an element of a power system when it suffers a short circuit or when it starts to operate in an abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. A number of criteria have been established for a protection relay, in order to operate properly is related to the minimum criteria, include reacting quickly, being selective, sensitive, and reliable (Blackburn and Domin, 2006: 18-22; Ram and Vishwakarma, 2001: 11-12; Glover *et al.*, 2010: 526; Rifaat, 2016).

Reacting quickly is interpreted as the ability to terminate parts of the system with faults that are carried out quickly, so that terminations quickly also with the aim of accelerating the achievement of the system performance again, minimized the possibility of damage, and minimized the possibility of further fault due to initial fault (Glover *et al.*, 2010: 526). Selective is interpreted as the ability of the relay to determine at which point the fault occurs so that the CBs can be chosen precisely so that only the faulty part is separated from the system (Glover *et al.*, 2010: 526). Sensitive means that the protection relay must be operational even though the fault that occurs is still at a light level (is called sensitive to all levels of fault). The higher the level of sensitivity, the more complex the series is and requires more components, thus impacting on financing (Singh, 2009: 151). Reliable means that the relay must operate in the conditions that

the relay should operate on (Rifaat, 2016).

The faults on the inside of the power transformers can also occur on the outside of the power transformers, as on the transformer terminals, which fall within the power transformer protection zone (Paithankar and Bhide, 2010: 80). The incipient faults in power transformer are faults which not significant in the beginning but which slowly develop into serious faults (Paithankar and Bhide, 2010: 96-98). The placement of the Buchholz relay (Paithankar and Bhide, 2010: 96-98) is shown in Figure 2.

Figure 2. The placement of the Buchholz relay

Based on Figure 2, the Buchholz relay provides protection against such incipient faults. The position of the Buchholz relay with respect to the power transformer tank and the conservator. The conceptual diagram of the inner working of the Buchholz relay (Paithankar and Bhide, 2010: 96-98) is shown in Figure 3.

Figure 3. The conceptual diagram of the inner working of the Buchholz relay

When an incipient fault occurs in the form of a winding to the core or an interturn on the power transformer winding, there is a severe heating point of the transformer oil. One of the two faults causes the gases to be liberated from the transformer oil in the range of values 350 °C. There is a build-up of transformer oil pressure,

causing oil to rush into the conservator tank through the interconnection piping (Paithankar and Bhide, 2010: 96-98). A vane is placed in the path of a surge of oil between the main tank of the power transformer and the conservator tank. A set of contact points that conducted by the mercury and operated by this vane is used as a trip command signal from the Buchholz relay for disconnecting the CBs. This output of the Buchholz relay may be used to trip the power transformer (Paithankar and Bhide, 2010: 96-98).

The Buchholz relay also has another set of contact points that conducted by the mercury and operated by a float. These contact points stay open (uncontacted condition) when the transformer oil is filled into the power transformer tank. However, if any leak case of the transformer oil or occurred the decomposition of transformer oil, then the float sinks, so that the contact points that conducted by the mercury to close (contacted condition). Loss of the transformer oil will inevitably cause the transformer temperature to rise, but does not warrant immediate tripping. Hence, normally these contact points are fix-wired to an alarm port that alerts the operator (Paithankar and Bhide, 2010: 96-98).

The trapped gases in the conservator tank can give a valuable clue to the type of specific damage that takes place on inside the power transformer, as the damages in the burnout over insulation between the core lamination stampings and the transformer oil or in the burnout over insulation between the turns of winding. Liberating the specific gases caused by all of the damages when there is heated up that caused by a fault. The specific gases that arise can be used as a phenomenon of a particular type of damage that may have happened at a particular point on inside the power transformer. The lists of information about the analysis of trapped gases (Paithankar and Bhide, 2010: 96-98) is shown in Table 1.

The amount of gas content caused by the fault is in the form of a ratio of gas to flammable gas in percent (%) (Myers *et al.*, 1981: 158-161; HRTSG, 2005). The group of gas type, the ratio of gas to flammable gas in percent (%), and its effects are shown in Table 2.

Based on Table 2, it can be explained that some of the gases arising from faults consisted of 70% in the form of hydrogen gas (H_2), and the rest is in the form of other gases (Myers *et al.*, 1981: 158-161; HRTSG, 2005).

The existence of a several of gases is

done through the analysis of dissolved gas (dissolved gas analysis, DGA), such as acetylene (C_2H_2), methane gas (CH_4), carbon dioxide (CO_2), and propane (C_3H_8) (Duval, 1989; Sun *et al.*, 2012; Mirowski, 2012; Liepniece *et al.*, 2017). The existence of a mixture of several gases, namely (i) H_2 and C_2H_2 , as a result of arising of arcing (arching) between conductors or iron core; (ii) H_2 , C_2H_2 , and CH_4 , due to the decomposed insulation of phenols that used in the tap changer; (iii) H_2 , C_2H_2 , CH_4 , and C_2H_4 gases as a result of heating on the core connection plate; and (iv) gases H_2 , C_2H_4 , CO_2 , and C_3H_8 , due to the decomposed insulation of turns (IEEE Std C57.104-2008, 2008; Myers *et al.*, 1981: 158-161; HRTSG, 2005).

A summary of the Buchholz relay, i.e. (i) gas accumulator relay; (ii) applicable to conservator tanks equipped; (iii) operates for small faults by accumulating the gas over a period of time and typically used for alarming only; (iv) operates or for large faults that force the oil through the relay at a high velocity, used to trip, and able to detect a small volume of gas and accordingly can detect arcs of low energy; and (v) detects high-resistance joints, high eddy currents between laminations, energy arcing in low and high, and accelerated aging caused by overloading (Hartman, 2018: 28).

2. MATERIALS AND METHODS:

2.1. Materials of Research

Installing the Buchholz relay and measuring its performance mounted on the power transformer, then the protective function measurements were carried out by the Buchholz relay. A set of circuits for measuring the performance of the Buchholz relay, in the form of an analogy to the main tank of a power transformer, the connecting pipe between the main tank analogy and the Buchholz relay, the connecting pipe between the Buchholz relay and the conservator tank analogy, the analogy of an oil storage tank, a pump, and the installation of several diaphragm valves. The end of the pipe comes from the main transformer tank is connected inside the conservatory on the bottom portion. A Schematic diagram of the circuit for measuring the performance of the Buchholz relay is shown in Figure 4.

Based on Figure 4, it can be explained that the performance measurement of the Buchholz relay is carried out, namely the

installation of a solenoid valve that operated through the push button to simulate the alarm and trip conditions. When the power transformer is loaded, and when the temperature of ambient temperature, the oil volume inside the power transformer increases. A conservator tank of power transformer provides adequate space to this expanded the transformer oil. It also acts as a reservoir for the transformer insulating oil. An electronic circuit-based control panel that is integrated with a circuit breaker operation was chosen as a means for creating conditions during alarm or trip.

2.2. Methods of Research

The flowchart of research methods is shown in Figure 5.

Figure 5. The flowchart of research methods

Based on the research flow diagram in Figure 5, it can be explained that the Buchholz relay performance measurement provides simulated fault conditions for setting on alarm and trip.

The stages of providing conditions for simulating an alarm or trip are guided by the experimental circuit in Figure 4. Prior to the simulation of the alarm, diaphragm valve #2 and diaphragm valve #3 was closed. The pressure indicator on the analogy of the main tank of the transformer (designated by pressure gauge #1) is higher than the designated by pressure gauge

#2, and the pressure indicator on pressure gauge #2 is higher than the designated by pressure gauge #3. The condition for the occurrence of an alarm is done by pressing the push-button switch once so that the solenoid valve is open for a moment. The momentary opening of the solenoid valve is a phenomenon of oil shock pressure, resulting in oil flow from the main transformer tank, which has a higher pressure than the oil pressure in the conservator tank. The change in oil pressure in the conservator tank results in a decrease in the position of the upper float downward, so that the contact point, which is on the upper float, is conducted by mercury. Conduction of this contact point results in sending an alarm signal to the control panel so that the buzzer sounds like an alarm signal.

Prior to the trip simulation, diaphragm valves #2 and #3 are open. The pressure indicator on the analogy of the main tank of the transformer (designated by pressure gauge #1) is higher than the designated by pressure gauge #2, and the pressure indicator on pressure gauge #2 is higher than the designated by pressure gauge #3. The provision of trip conditions is carried out by pressing the push-button switch continuously so that the solenoid valve is open for a long time. The continuous opening of the solenoid valve is a phenomenon of oil flow from the main tank of the transformer to the conservator tank. Oil flow occurs because the pressure in the main tank of the transformer is higher than the oil pressure in the conservator tank. The occurrence of oil flow to the conservator tank results in changes in the position of the lower float in the direction of the oil flow for a long time so that the contact point, which is on the lower float, is conducted by mercury. Conduction of this contact point results in sending a trip signal to the control panel so that the control panel carries out the CBs operation to the OFF condition and the buzzer also sounds.

3. RESULTS AND DISCUSSIONS:

The Buchholz relay was invented and implemented in 1921 by Max Buchholz, in Kassel. The Buchholz Relay is used as a protection purpose, which is sensitive to the effects of dielectric transformer oil failure on inside the equipment and installed to monitor large power transformers for oil loss or insulation breakdown. In the Buchholz relay, there is a hollow space or chamber which is placed between the tank of the transformer and

conservator. When the winding of the transformer is heated, or there are any fault occurs, flammable gas is produced, which tries to occupy the upper segment of the space of the chamber that containing the oil. The occupation of the flammable gas in the upper segment of the space will be possible only when the level of transformer oil goes down. When a small fault occurs, then the level of transformer oil goes down slightly.

The Buchholz relay is an essential component of the oil-immersed power transformer protection philosophy. This device detects the gas accumulation that formed by (i) the oil degeneration in partial discharges and (ii) disconnecting the transformer in large faults due to the oil flow. Those two things are caused by internal electrical short-circuits and arcing. The Buchholz relay is a type of mechanical relay whose operating mechanism is influenced by oil and gas in the transformer tank. The use of the Buchholz relay functions as a protective relay on the oil-immersed power transformer to anticipate internal faults that may occur, such as the failure of the oil function as a cooling and insulation media or the failure of solid and liquid insulation on the coil, or other reasons.

The Buchholz relay is usually connected in a chain with the piping that interconnection with the main tank of the power transformers oil to the expansion tank; in this manner, the gases produced inside by eventual intermittent or persistent malfunctions tend to move into the expansion tank through the interconnecting piping. The Buchholz relay then captures and retains this gas in its chamber where a relay mechanism will be activated after the gas build-up has reached a certain level, which in turn, enables the alarm contact float (1st level).

The type of physical form and explanation of each Buchholz relay is shown in Figure 6. Based on Figure 6 can be illustrated with detail of part in the chamber of the Buchholz relay. The cross-section of details of the Buchholz relay construction is shown in Figure 7.

Source:

<https://www.electricalclassroom.com/buchholz-relay-working-principle/>

Figure 7. The cross-section of details of the Buchholz relay construction

Based on Figure 7 can be explained; that a typical Buchholz relay will have two sets of contacts that are conducted by the mercury. One is arranged to operate for the slow accumulation of gases, the other for the bulk displacement of transformer oil in the event of a substantial internal fault. When an alarm is generated for the former, but the latter is usually direct-wired to the relay contact of the trip condition for operating the circuit breaker. Therefore, the device sounds an alarm for the following abnormal conditions, all of which have a low level of urgency: (I) hot spots on the core due to short circuit of lamination insulation, (II) core bolt insulation failure, (III) faulty joints, (IV) inter-turn faults or other winding faults involving only lower power infeeds, and (V) reduced oil volume due to leakage. When a major fault on winding occurs, this causes an oil surge, which moves the lower float to a lower position and thereby causes decreasing the insulation capability of the power transformer. This action will take place for: (a) all severe winding faults, either to earth or inter-phase, and (b) loss of oil if allowed to continue to a dangerous degree.

In the invention of improved Buchholz relay (Dal Lago, 1999) explained that switches operated by fluid change pressure, by pressure waves on fluid, or by the turn of the fluid flow actuated by devices allowing the continual flow of fluid, e.g., vane the switch being of the reed switch type. A Buchholz relay comprising, to be

immersed in an oil bath, a supporting frame for magnetic switches for closing circuits which are operated by portable devices, of which at least one is of the floater type, and at least one is of the type with a flap rotatably associated with the frame. The moveable flap device, which has a surface that is sensitive to the presence of oil flows.

The movable flap device is independent of said floaters and comprises a flat member provided with a pivot that is rotatably associated with said frame by way of its ends. It also has a surface that is sensitive to the presence of oil flows, so that said movable flap device is able to rotate with respect to the said frame under the oil flow action. At least one part of the surface of the moving flap device, which is sensitive to the presence of oil flows, can also be reduced. Characterized in that device, prefractures are formed in said flat member so as to constitute said reducible surface, prefractures forming at least one detachable portion.

According to characterized in that device, including (a) said movable flap device comprises tubular support inside which a counterweight can be inserted; (b) mutually opposite guides for the sliding of the ends of the said pivot are formed in said frame, the end of each guide with an adapting seat for the snap insertion of the end; and (c) said movable flap device is made of plastics.

The steps to test the Buchholz relay is done through positioning on "test mode". Then followed by the testing stages, i.e. (a) short-circuit the alarm contacts and checked if the annunciation is received at the control room, and then short-circuit tripping contact and verified whether the trip command is issued to the circuit breaker; (b) injected the air into the Buchholz relay from the pet valve provided at the top of the relay, to simulated the gas accumulation and checked the alarm and tripping; and (c) drain the transformer oil from the relay, after closing the gate valves provided at both the sides of the relay in the interconnection piping and checked the annunciation and tripping.

The measurement results of the protective function of the Buchholz relay is shown in Table 3. Based on Table 3, it is shown that the measurement results of the protection function of the Buchholz relay are performed by the simulation of faults by pressing the push-button one time to simulate the existence of an alarm condition in which the control panel of the CBs does not operate. However, the appointment of an alarm signal, so that the Buzzer sounds and

the status check trip is still normal or "no lock-out". Giving full pressure as a form of simulation for trip conditions on the Buchholz relay, the control panel designates the status of the two CBs (150 kV side and 20 kV side) open, and the alarm signal designation also occurs with Buzzer sounding. Hence, the check trip status becomes "lock-out".

The schematic diagram and the mechanism of operation of the Buchholz relay are shown in Figure 8. Based on Figure 8, it can be explained, that the type of fault that occurs and must be overcome by the Buchholz relay, namely: (i) a mild fault that results in a gas bubble flowing to the top of the relay and pressure that results in the upper float moving downward, so that the contact mercury is connected and giving an alarm signal, so that the buzzer alarm sounds and (ii) severe disturbances that result in gas and oil shock and there is a pressure that causes the lower float to move downward, so that the contact point conducted by is mercury and the signaling occurs trip.

The Buchholz relay serves to detect the presence of gases caused by local heating or pressure surges in the transformer oil. When oil-insulated power transformers are located indoors, it is often necessary to isolate these transformers in a fireproof vault because of fire hazards. On the other hand, relays are not responsive to external pressures. No servicing required throughout the function. The illustrations for the alarm and trip phenomena are depicted in the form of a schematic diagram. The schematic depiction of the cross-section and specific parts of the Buchholz relay is shown in Figure 9. Based on Figure 9, it can be explained that specific parts of the Buchholz relay play an essential role in the alarm and tripping processes. It was also shown that maintenance is required for correct alarm and tripping conditions.

The schematic diagram explanation, under normal circumstances, the Buchholz relay is filled with transformer oil. Providing conditions with initial/minor/incipient fault, suppose that a short circuit occurs in the winding of the transformer, then gas is generated due to local heating from solid and liquid insulation. The resulting gas collects on the upper surface of the Buchholz relay, and when there are enough, there is an emphasis on the upper float, so the float changes position, which impacts the operation of the mercury contact point (alarm signal contact). The schematic diagram of the operation of contact points conducted by mercury on the Buchholz relay for alarm signal is shown in Figure 10.

A case of arc arises because of the existence of a short circuit between phases resulting in arcing arising. The inter-phase coils are located in a tank submerged by transformer oil; because the oil reacts to the heat generated by arcing arcs, then C_2H_2 gas is formed and enters the Buchholz relay; so that the presence of gas by operating alarm contacts. For conditions where the fault continues, pressure on the transformer oil arises; so that under certain pressure, a contact trip operation can occur. The schematic diagram of the operation of contact points conducted by mercury on the Buchholz relay for trip signals is shown in Figure 11.

5. CONCLUSIONS:

Based on the results and discussions, conclusions can be drawn according to the research objectives. The provision of faults simulation in the form of pressing a push-button 1 (one) time to simulate the existence of an alarm condition, in that condition, the CBs control panel does not operate, but the appointment of an alarm signal, so that the Buzzer sounds and the status check trip is still normal or "no lock-out". Giving full pressure as a form of simulation for trip conditions on the Buchholz relay, the control panel designates the condition of the two CBs (150 kV side and 20 kV side) open, and the alarm signal designation also occurs with Buzzer sounding. Hence the check trip status becomes "lock-out". The illustrations for the alarm or trip phenomenon are depicted in the form of a schematic diagram. The inter-phase coils are located in a tank submerged by transformer oil because the oil reacts to the heat generated by arcing arcs, then C_2H_2 gas is formed and enters the Buchholz relay; so that the presence of gas by operating alarm contacts. For conditions where the disturbance continues, pressure on the transformer oil arises; so that under certain pressure, a contact trip operation can occur.

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Figure 1. Schematic diagram of the complete structure of the oil-immersed power transformer

Figure 4. Schematic diagram of the circuit for measuring the performance of the Buchholz relay

Source: <https://docplayer.net/docs-images/99/143315317/images/67-0.jpg>

Source: <https://circuitpedia.com/wp-content/uploads/2020/05/buchholz-relay-construction.png>

Figure 6. The physical form and explanation of each Buchholz relay

Source: <http://electricalengineering-eg.blogspot.co.id/2014/02/buchholz-relay.html>

Figure 8. The schematic diagram and the mechanism of operation of the Buchholz relay

Figure 9. The schematic depiction of the cross-section and specific parts of the Buchholz relay

Figure 10. The schematic diagram of the operation of contact points conducted by mercury on the Buchholz relay for alarm signal

Figure 11. The schematic diagram of the operation of contact points conducted by mercury on the Buchholz relay for trip signals

Table 1. The lists information about the analysis of trapped gases

Type of Gas	Diagnosis
H ₂ and C ₂ H ₂	Arcing in oil between constructional parts
H ₂ , C ₂ H ₂ , and CH ₄	Arcing with some deterioration of phenolic insulation, e.g., fault in tap changer
C ₂ , CH ₄ , and C ₂ H ₄	Hot spot in core joints
H ₂ , CH ₄ , CO ₂ , and C ₃ H ₆	Hot spot in a winding

Table 2. *The group of gas type, the ratio of gas to flammable gas in percent (%), and its effects*

Group of Gas Type	Ratio* in (%)	Its effects
H ₂ C ₂ H ₂ CH ₄ C ₂ H ₄ C ₂ H ₆	60.0 30.0 5.0 3.3 1.6	Leap of sparks in oil (and jumps occur in the paper when there are CO and CO ₂ contents)
H ₂ CH ₄ C ₂ H ₆ CO C ₂ H ₄ C ₂ H ₆	86.0 13.0 0.5 0.2 0.2 0.1	Corona in oil (and Corona in the paper if there are CO and CO ₂ content)
C ₂ H ₄ C ₂ H ₆ CH ₄ CO H ₂	63.0 17.0 16.0 trace trace	Overheating (if there is a C ₂ H ₂ content, there may be interference or short circuit)
CO H ₂ CH ₄ C ₂ H ₆ C ₂ H ₄ C ₂ H ₂	92.0 6.7 1.2 0.01 0.01 0.01	Overheating (if there is a C ₂ H ₂ content, there may be interference or short circuit)

Ratio* = ratio of gas to flammable gas

Table 3. *The measurement results of the protective function of the Buchholz relay*

Protecting Object	Giving the Simulation of Fault	Condition of CBs (opened)		Panel of Control	Protection Panel	Alarm	Check Trip
		150 kV side	20 kV side				
Alarm from Buchholz	pressed one time	-	-	Buchholz Alarm Indication	-	yes	-
Trip from Buchholz	fully pressed	yes	yes	Buchholz Trip Indication	MVAJ: ½ is operated	ya	lock-out