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Enhancing Power System Resilience through Advanced Transformer Protection Techniques

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Abstract: *This research paper explores modern techniques for enhancing transformer protection in power systems, addressing challenges like overloading and faults. The study advocates for the integration of intelligent electronic devices, artificial intelligence, and predictive analytics to create adaptive protection schemes. Simulation studies demonstrate the superiority of these approaches, emphasizing improved reliability, reduced downtime, and enhanced grid resilience. The findings contribute valuable insights for power system operators and engineers seeking to fortify electrical grids in the face of evolving challenges.*

Keywords: Transformer protection, Power system resilience, Intelligent electronic devices (IEDs), Artificial intelligence (AI), Machine learning, Deep learning, Adaptive protection schemes, Fault detection, Overloading, Predictive analytics, Real-time monitoring, Sensor networks, Communication protocols, Simulation studies, Grid resilience, Electrical infrastructure, Preventive measures, Economic benefits, Operational benefits, Case studies.

I. INTRODUCTION

Transformers are one of the most important and expensive components of any power distribution system. It is a sealed, static device, usually immersed in oil, so there are no limits. But the effects of rare defects can be very dangerous for transformers, and the long operating time for repair and replacement of transformers worsens the situation. Therefore, protection of power transformers becomes very important.

Faults occurring in transformers are generally divided into two types: external faults and internal faults. Internal faults often arise from sensors and measurement systems.

Transformer Protection for Different Types of Transformers

The protection used in power transformers depends on the type of transformer. The table below is,

Category	Transformer Rating - KVA	
	1 Phase	3 Phase
I	5 - 500	15 - 500
II	501 - 1667	501 - 5000
III	1668 - 10,000	5001 - 30,000
IV	> 10,000	>30,000

Transformers in the 500 KVA range belong to (Classes I and II) and therefore have a fused protection block, but transformers below 1000 kVA have protected 11kV and 11kV distribution transformers) usually 33kV) use medium voltage circuit breakers.

Different relays should be used to protect transformers of 10 MVA and above (Class III and IV).

In addition, mechanical relays such as fuel relays and current voltage relays are also widely used in transformer protection. In addition to these relays, thermal overload protection is often used to extend the life of the generator rather than to detect faults.

Protection Transformer Types

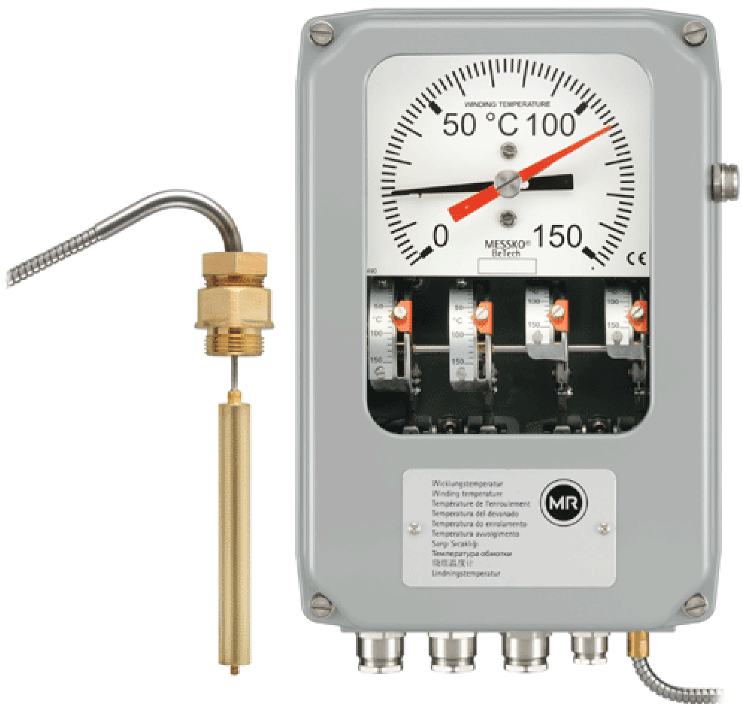
1. Preventing overheating
2. Overcurrent protection
3. Transformer differential protection
4. Soil protection (limited)
5. Gas (Gas Detection) Relay
6. Overcurrent protectionTransformer

Overheating Protection

Overheating of the transformer due to overload and short circuit conditions. The permissible overload and corresponding duration depend on the transformer type and the insulation class used in the transformer.

Higher load can be stored for a short time, if continued for a long time it will damage the insulation of the transformer due to higher-than-expected temperature. The temperature of oil-cooled transformers is considered to be a maximum of 95*C, above which the life of the transformer will decrease and the insulation of the wires will be negatively affected.

Therefore, it is important to prevent overheating. Large generators have oil or gas thermometers to measure the temperature of the oil or gas; There are generally two measurement methods; one is called thermometer and the second is called temperature index. . The figure below shows a Type Reinhausen thermometer with thermometer box for measuring the temperature of liquid-insulated protective transformers.



On the box there is an indicator dial (black pointer) that shows the temperature of the transformer and a red pointer that shows the alarm light spot. If the black pin exceeds the red pin, the device will activate the alarm.

Looking at the bottom, we can see four arrows with which we can set the device for alarm or motion, or use it to start or stop the pump or cooling fan.

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As seen in the picture, the thermometer is mounted on the core and windings at the top of the transformer tank, this is done because the highest temperature will be in the middle of the core and windings. tank. This temperature is called the maximum oil temperature. This temperature allows us to estimate the temperature of the transformer core. Currently, fiber optic cables are used to accurately measure the temperature of the transformer in low voltage windings. This is how overheat protection is used.

Overcurrent Protection of Transformers

Overcurrent protection systems are one of the oldest protection systems developed, leveled overcurrent systems are designed to protect against overcurrent conditions. Distributors use this method to detect errors with the help of IDMT relays. So the relay contains:

1. Reverse power and
2. Minimum working hours.

IDMT relays have limited functions. Such relays must be set at 150% to 200% of the maximum current, otherwise the relay will operate in an overload condition. Therefore, relays provide less protection against faults in the transformer tank.

Differential Protection Transformer

Percentage bias current differential protection is used to protect power transformers. This type of protection is used on transformers larger than 2 MVA.

There is a star connection on one side of the transformer and a delta connection on the other side. The CTs of the star are delta connected and the CTs of the star are star connected. The neutral points of both transformers are connected to ground.

The transformer has two coils; one is the working coil and the other is the stepper. As the name suggests, the limit coil is used to create control force and the coil is used to create operating force. The current limiting coil is connected to the secondary winding of the current transformer and the operating coil is connected to the equipotential points of the CT.

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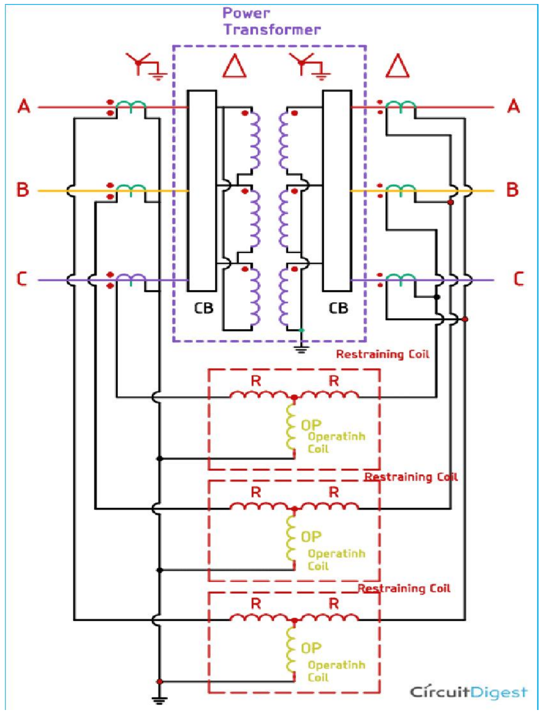
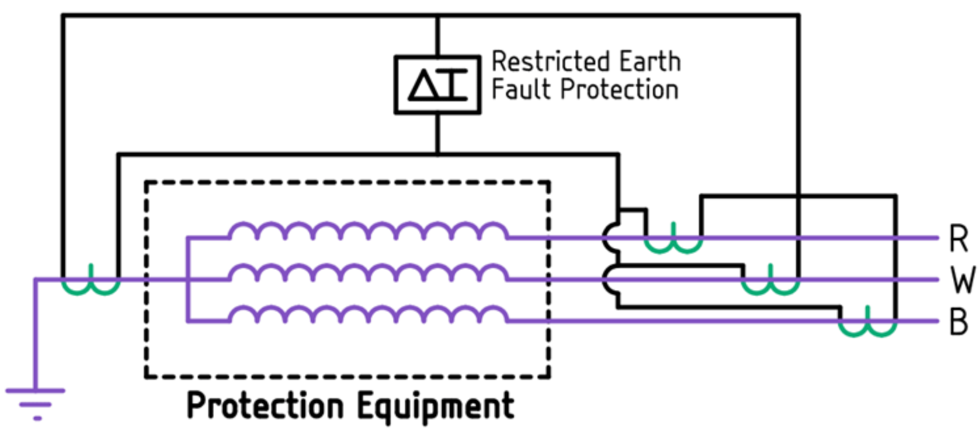


The principle of transformer protection is different:
The starting coil is currently not available. winding, balance switch and differential relay. The operating coil starts to create a difference between the two sides of the transformer. Therefore, the relay goes around the circuit breaker and protects the main transformer.

Earth Protection Limited



When the transformer fails, a large amount of fault water will flow. In this case, the fault must be repaired as soon as possible. The ability to act on a protection must be limited to the area of the transformer; This means that if a ground fault occurs in a different location, the relay must be sent to the area where it should be, while the other relays must remain unchanged. That is why this relay is called limited earth fault protection relay.
In the picture above, the protection device is on the protection side of the transformer. We think it is side one and we also think there is a ground fault on both sides of the transformer. Now, if there is a fault on the ground side, there will be zero difference due to the ground fault and it will only flow to the second side. And it will not affect the primary side of the transformer.

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This relay has three phases and in case of a fault it will have three components; positive transient component, negative transient component and zero transient component. As the good straw season 120* is removed all current will flow through the protection relay at any given time. Therefore, since they are displaced by 120*, the sum of their currents will be equal to 0. The situation is similar to temporary negativity.

Now let's assume that a fault event occurs. This fault will be detected by the CT because the number of phases is high and current starts to flow through the protection relay and when this happens, the relay goes off and protects the transformer.

Buchholz (Ready Measurement) Relay

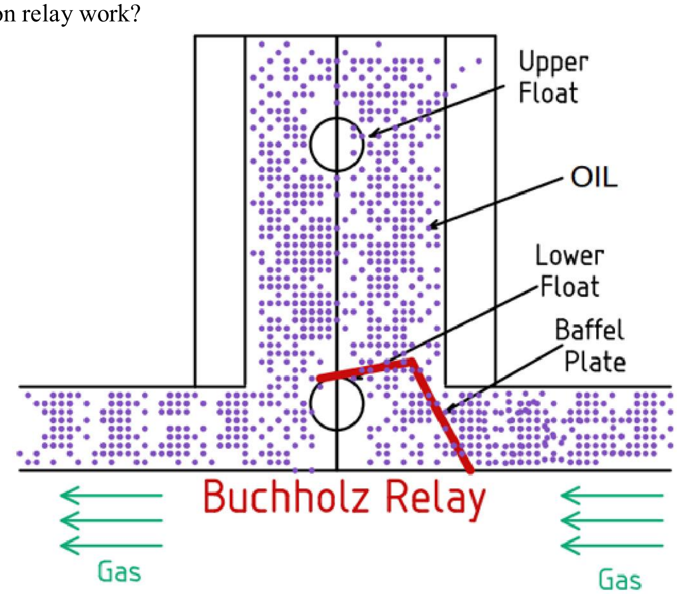
The image above shows a fuel relay. The Buchholz relay is mounted between the main transformer unit and the storage tank and captures the separated oil with the help of a float switch when a fault occurs in the transformer.

If you look closely, you can see an arrow where the oil flows from the main tank to the storage tank. Most gas is called gas, and nine different types of gas are produced depending on the crime. There are two valves at the top of the relay, these valves are used to reduce gasoline and are also used to remove the fuel sample.

When a problem occurs, sparks may appear between the windings or between the windings and the core. The small current remaining in the windings heats the insulating oil, which decomposes and thus produces gases, the weight of which can be detected in the resulting glass.

Large energy output will produce acetylene and as you know acetylene production requires a lot of energy. And you should remember that all faults will produce gas and we can see the fault by analyzing the gas.

How does the gas detection relay work?



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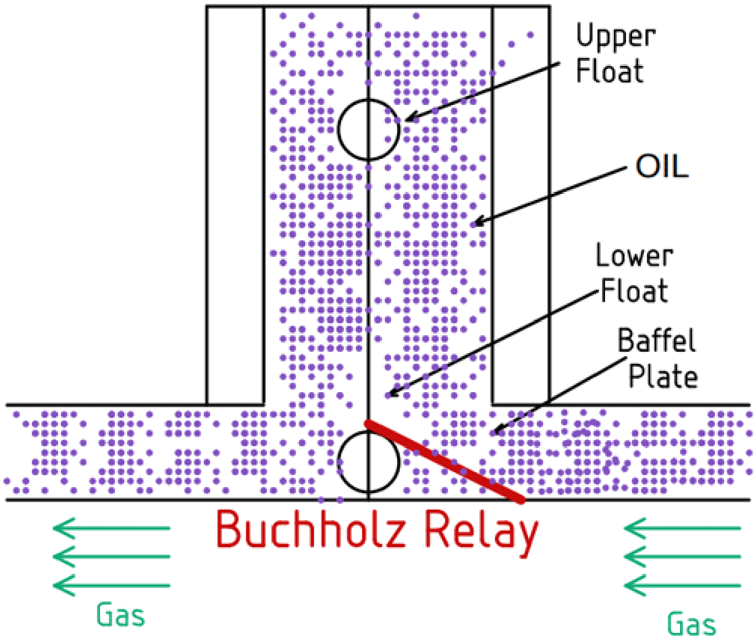
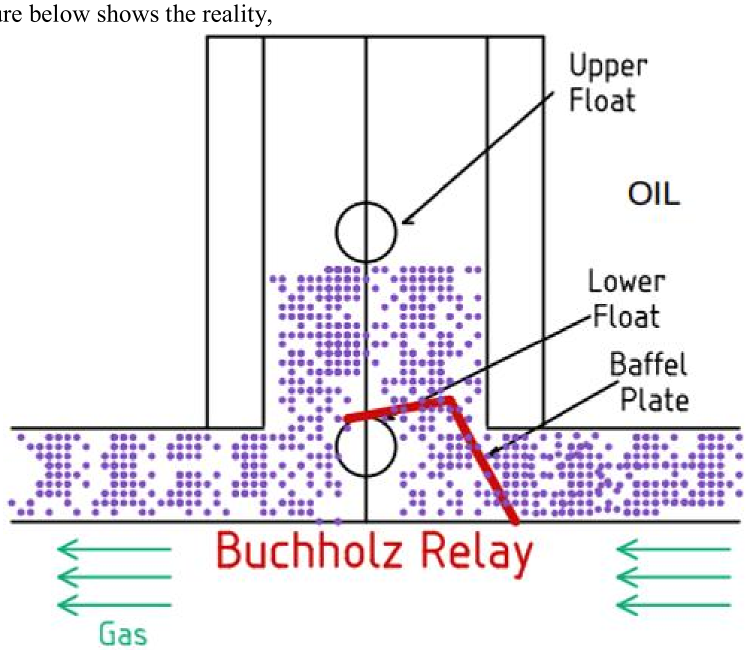
As you can see in the picture, we have two floats: an upper float, a lower float and a baffle plate that pushes the float. When a major electrical problem occurs it creates more oil than flows through the pipe which moves the baffle and forces the float down, now we have a combination together, the top float is up, the bottom float is down and the baffle board is tilted. This combination indicates that a serious sin has been committed. He turned off the transformer and raised an alarm. The picture below shows the reality,



But this is not the only situation where this relay is useful, consider the situation where a small arc occurs in the transformer, these arcs produce small arc gas, this Gas is the pressure produced in the relay, the upper float falls and the gas inside is released , this time the relay alarm is given, the upper float falls, the lower float remains unchanged, and the baffle plate remains unchanged. If this is the configuration. detected, we can conclude that the gas gradually accumulates. The picture below shows the reality,



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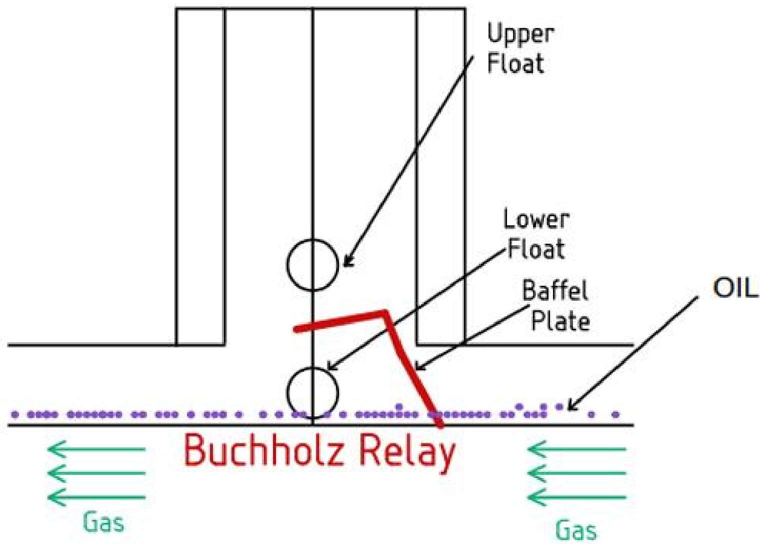
Now we know there is a fault, we will release some gas using the valve on the relay and by examining the gas we will find the exact cause of oil production the relay is in good condition Check for oil loss due to water leakage in the generator chassis. This In this case, the upper water flow, the lower flow water and the baffle plate remain in the same position. In this case, we receive a different warning. The picture below shows how it works.



Fault control in fuel relays can be done with these three methods.

Over-flux protection

Transformers are designed to operate at constant flux levels; Above this the magnetic flux level becomes saturated and the core becomes saturated. It quickly leads to other parts of the transformer, resulting in overheating of components and hence there must be over-flux protection as well as protecting the transformer core. Overflow conditions may occur due to overvoltage or reduced system frequency.

Overcurrent relay is used to protect the transformer from overcurrent. The flux density in the core is calculated by measuring the voltage/frequency ratio of the flux relay. A rapid increase in voltage due to a change in electrical power can cause excessive flux, but the changes are rapid and hence there is no need for sudden electrical change of the generator.

Magnetic flux density is proportional to the ratio of voltage to frequency (V/f) of a microcontroller-based relay. Voltage and frequency are measured over time, then the ratio is calculated and compared to previously calculated values. The relay is programmed to turn on the minimum time (IDMT characteristic). However, if necessary, the adjustment can be made manually. In this way, the target can be achieved without affecting the protection efficiency. We now see the importance of preventing the transformer from tripping due to excessive magnetic flux.

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