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RE-Konnect

Risk Engineering Bulletin

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In Focus:
Electrical Transformers

Editor's Note

Whether in infrastructure systems, industry or households, transformers always play a key role in the reliable transmission and distribution of power. Transformers are one of the most used electrical equipments in the world after Motor. An electrical transformer is defined as a static device that transforms electrical energy from a circuit to another without direct electrical connection, assisted by mutual induction between the two windings. It can transform power from one particular circuit to another without altering its frequency, though the voltage level may differ after the transformation. Transformer fires are fearsome events, perhaps the most dangerous common threats to human life—both onsite and beyond the boundaries of a power plant—that can hit an electric utility. They are the nightmares of electrical system operators. In this issue of RE-Konnect, we provide you some interesting facts on Transformers, reasons behind Transformer failure and some precautionary tests for finding out health of the transformer.

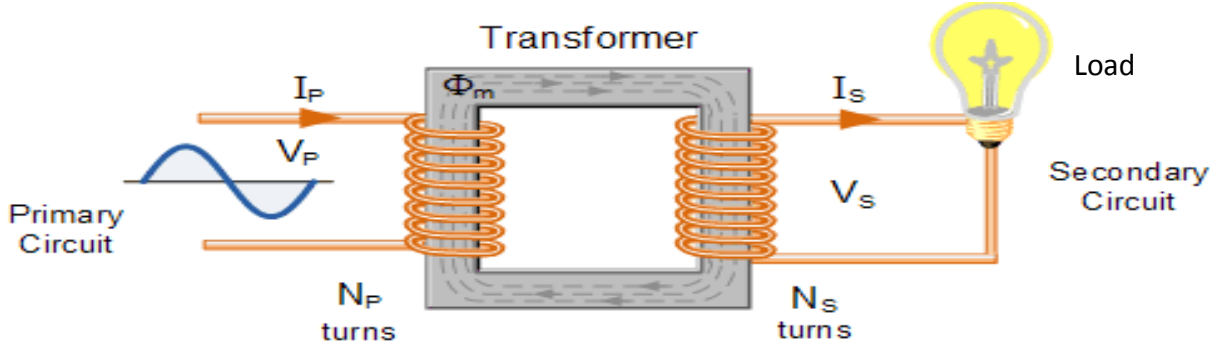
Did You Know?

- The idea of a transformer was introduced back in 1880. About 70 years later, in 1950, first transformer of 400KV electrical power was introduced in high-voltage electrical power system.

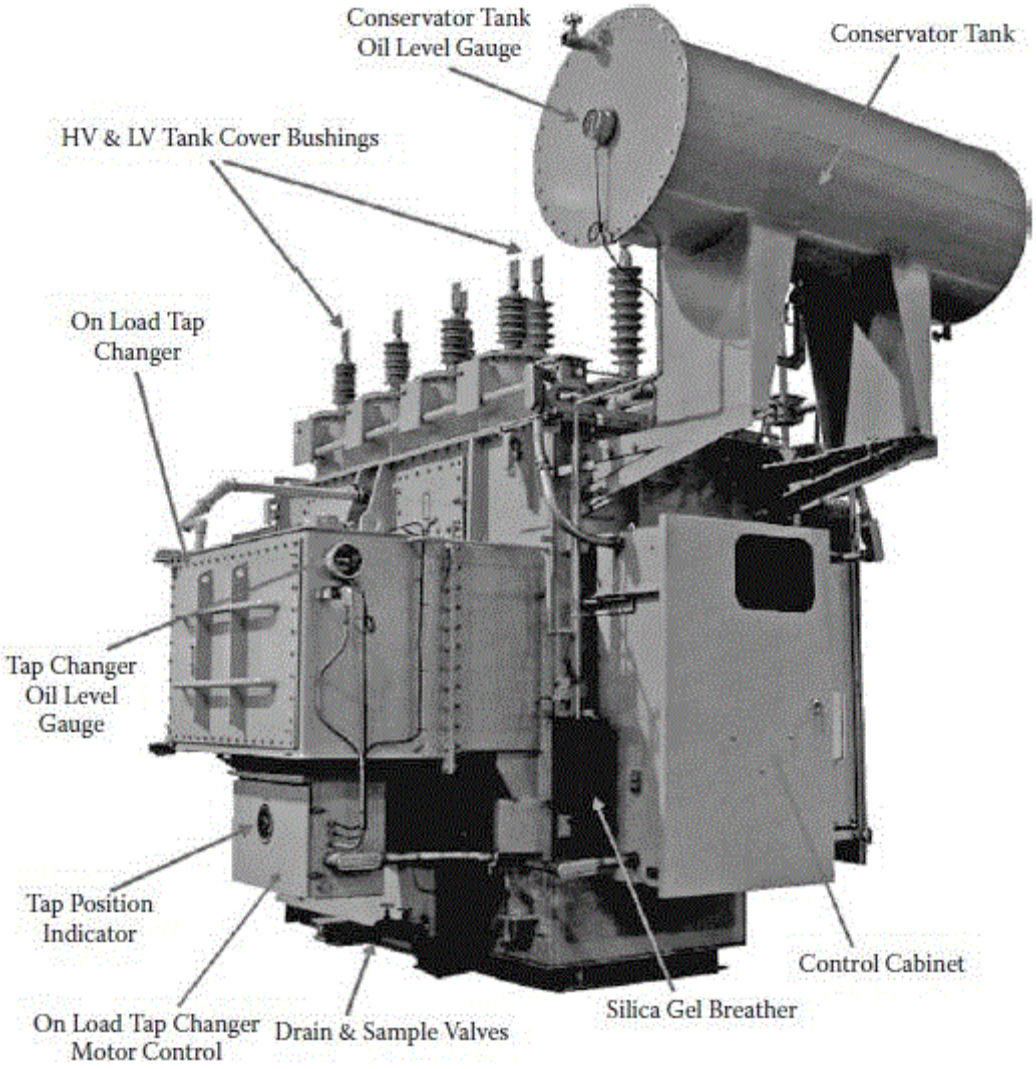
- A condition exists in which a transformer produces the same voltage on its secondary as is applied to its primary winding. This type of transformer is called an "Impedance Transformer"

- The best Electrical breaker technology trips in 50 milliseconds, far too late to prevent the explosion because most of the gases are generated within milliseconds after short-circuit.

- During a transformer short-circuit, the electrical arc vaporizes oil and creates a Dynamic Pressure Peak which travels at the speed of 1,200 meters per second (4,000 feet per second).



Know Your Transformer



Flavours of the Month

Transformers for Renewable Energy Generators

Power transformers connecting renewable energy generators to the grid have to cater for a set of circumstances not found in conventional generators based on rotary machines. Both solar PV and wind use inverters to convert DC to AC at the grid frequency, which have their own peculiar set of behaviour. Because each inverter has a different profile, the transformer has to be designed specifically for each installation. Some of the special requirements are:

- ***High harmonics***: Harmonics generated by the inverter cause higher eddy current losses and the transformer core has to be designed to take harmonics into account.
- ***Transients:*** Voltage Ramp rate from renewable energy sources can be rapid and transformers are needed to design to cater the situation.
- ***Interface with inverters:*** Short circuit performance of inverters is significantly different from rotating generators, and varies from supplier to supplier. The transformer has to be designed to cater to specific inverter used.

Causes of Failure and Loss Prevention

Why Transformers Blast

Transformers are generally highly reliable and failures are rare. Although most transformer faults do not lead to a fire or explosion, some combinations of latent faults may result in a catastrophic transformer fire. Following circumstances could lead to transformer fire and explosion.

- Failure of inter-turn insulation in the main windings, probably as a result of overheating due to obstruction in oil circulation; mechanical damage of insulation during manufacturing; moisture penetration between turns; overheating due to overvoltage or overload; and relative movement between turns.
- Insulation failure between winding and transformer oil tank caused by aging or deterioration of insulation, or moisture entry into oil.
- Failure of magnetic circuit, leading to excessive eddy currents in the core.
- External causes, such as rapidly fluctuating load, steep-fronted surge voltage and external short circuit on the secondary side.
- Miscellaneous faults: failure at connections or bushing; inadequate design or a design unsuited to the service for which the transformer was installed; inadequate spring tension on tap-charger contact springs; ignition of vapour above the oil level; and inadequate maintenance.
- A heavy overload degrades the oil sufficiently to cause a fairly high leakage current. The leakage current further degrades the insulation (i.e. oil, paper or wood) and eventually leads to a turn-to-turn or layer-to-layer fault.
- The fault becomes large enough to cause the primary fused cut out to operate.
- The energy released from the arc gassifies the transformer oil, primarily into hydrogen and methane, which is highly flammable.
- The combustible escaping gases ignite either due to remaining arc energy or due to sparking associated with rapid metal breakage.

Because “there is nothing that cannot be improved” continuous improvement must be an integral part in all processes. The power transformer protection is realized with two different kinds of devices, namely the devices that are measuring the electrical quantities affecting the transformer through instrument and the devices that are indicating the status of the physical quantities at the transformer itself.

An example of the former could be current-based differential protections and of the latter oil temperature/condition monitoring.

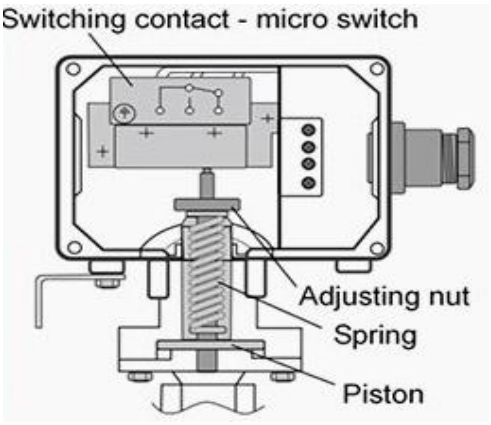
Protection Devices

Below are the typical devices used for protection:

1. ***The Buckholtz Relay:*** The Buchholz protection is a mechanical fault detector for electrical faults in oil-immersed transformers. The Buchholz (gas) relay is placed in the piping between the transformer main tank and the oil.

Bukholtz Relay

2. ***Pressure Relay:*** Many power transformers with an on-tank-type tap changer have a pressure protection for the separate tap changer oil compartment. This protection detects a sudden rate-of-increase of pressure inside the tap changer oil enclosure.



Pressure Relay

3. ***Oil Level Monitor:*** Transformers with oil conservator(s) (expansion tank) often have an oil level monitor. Usually, the monitor has two contacts for alarm. One contact is for maximum oil level alarm and the other contact is for minimum oil level alarm.

4. ***Winding Thermometer:*** The winding thermometer creates an image of the hottest part of the winding. The top-oil temperature is measured with a similar method as introduced earlier. The measurement is further expanded with a current signal proportional to the loading current in the winding.

Winding Thermometer

Apart from the above mentioned devices other important mountings are Silica Gel filled Breather box, Fire walls, Lightening Arrester are some Protective devices are installed on or near to transformers.

How to Predict the Health of Transformer

Dissolved Gas Analysis (DGA) of Transformers

DGA is related to liquid insulation that is transformer oil. Due to faults that are happening inside the transformer heat will be formed and due to this energy the long organic oil chain is getting broken. As a result so many gases is formed. The main gases examined are:

- Atmospheric gases: nitrogen and oxygen
- Oxides of carbon: carbon monoxide and carbon dioxide
- Hydrocarbons: acetylene, ethylene, methane and ethane
- Hydrogen

How to analyze result

- Insulation overheating deteriorates the cellulose insulation. In this case DGA results show high carbon monoxide and high carbon dioxide. In extreme cases methane and ethylene are at higher levels.
- Oil overheating results in breakdown of liquid by heat and formation of methane, ethane and ethylene.
- Corona is a partial discharge and detected in a DGA by elevated hydrogen.
- Arcing is the most severe condition in a transformer and indicated by even low levels of acetylene.

Furan Testing of Transformers

Furan Analysis on transformer oil indicates the degree of degradation of the transformer paper insulation. This is usually done in transformers aging above 15 years. Furan analysis shows the condition of the paper insulation with an oil sample. Over time, the cellulose insulating material will experience degradation. When the degree of polymerization or tensile strength has fallen to around 200, the paper is so weak that any stress will lead to failure, for a new insulation paper it is > 1000. The life of the paper insulation is typically the life of the transformer. An aromatic compound is produced during this degradation called furan. Testing is performed for five furans:

- 5H2F (5-hydroxymethl – 2-furaldehyde)—oxidation;
- 2FOL (2-furfurol)—high moisture;
- 2FAL (2-furaldehyde)—overheating, old fault;
- 2ACF (2-acetylfuran)—rare, lightning; and
- 5M2F (5-methyl – 2-furaldehyde)—local, severe overheat.

Find Out the Health of your Transformer

Furan Content (ppm)	DP Value	Significance
0-0.1	1200-700	Healthy transformer
0.1-1.0	700-450	Moderate deterioration
1-10	450-250	Extensive deterioration
>10	<250	End of life criteria

Guidelines

Following codes and standards should be referred for Transformers:

- **IEC 60076 :** Power Transformer
- **IS SP 30 (2011):** National Electrical Code 2011
- **ASTM D3612 :** Dissolved Gas Analysis
- **ASTM D5837:** Furan Compound

Engage

Answer the following questions to win Amazon coupons worth Rs 500 each. Send the answers to editor.bulletin@tata-aig.com. 10 prizes will be given and winners will be announced in next issue.

Q1. Which test you would like to conduct for relatively new Transformer?

a) DGA b) Furan Analysis

Q2. High percentage of Hydrogen indicates?

a) Corona Discharge b) Oil Overheating

Q3. Which are the main gases generated in Transformers after the short circuit/Arc
a) Hydrogen and Methane b) CO & CO2

Winners of the previous issue are as follows:

- **Vishal Purohit**, Munich RE – Mumbai
- **G Sureshbabu**, Madura Coats – Bangalore
- **Vikas Singh**, Petronet LNG – Kochi
- **Dipan Panja**, GIC of India – Mumbai

Answers to previous questions: 1. Smoking 2. Spinning 3. All of the above

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