NEWSLETTER FOR MANUFACTURING COMMUNITY

Maintenance Circle

Word for the day: **UNDERSTANDING 11KV/415V-AC TRANSFORMER**

Long since Michael J Faraday and other great scientists discovered electricity, it has become an integral part of our very existence today. No machine can work without using electricity, directly or indirectly. Although the earth has been rotating around Sun for billions of years, today our life will almost come to a standstill without this “invisible” power of electricity.

There are thousands of equipments which work on electrical power and they all operate on different voltage levels, both on AC & DC circuit, varying from few milli volts to thousands of kilo volts. Independent of all technological changes and advancements that has taken place in electrical field, one equipment remains indispensible and is the most essential component in electrical power transmission & distribution: *Transformer*.

Although, transformers[1] are available in different variations to suit specific applications, operating on both AC & DC voltage, in this newsletter we will elaborate a little on the standard AC step-down transformer reducing the high tension (HT) voltage of 11,000 (or 33,000) AC to more usable low tension (LT) 415V AC at 50 / 60 Hertz (50 / 60 Cycles Per Second. Hertz is used as recognition to inventor-scientist, Heinrich Hertz who invented radio frequency).

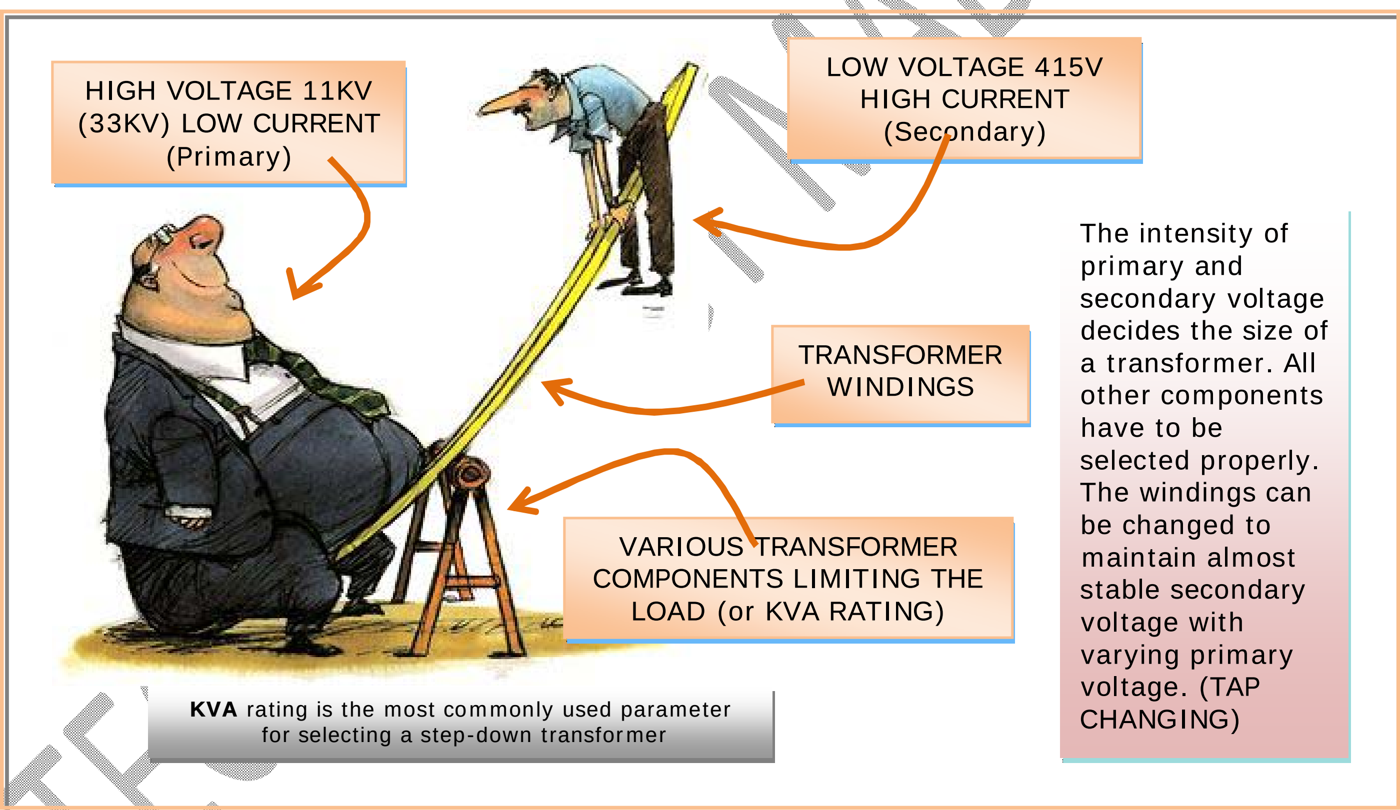

Figure 1

It is pretty difficult to imagine a manufacturing set-up without a “dedicated” or “common” step down transformer, hiding somewhere in one corner – usually covered with tree branches, bird-nests and dust – and supplying the required voltage to various machines. These transformers receive 11,000 (or 33,000)

[1] Transformer: Something that “transforms” or changes one type to other type

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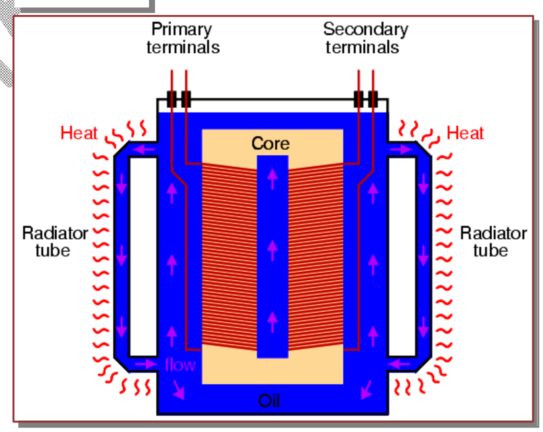
volts HT supply from state electricity and reduce it to 415V LT supply at different current ratings. For practical purposes, let us try to study two topics in this newsletter: I) Understanding some of transformer specifications II) Basic care required at transformer yard. We will just touch upon the components a transformer is made of, in couple of paragraphs at the end.

The step-down transformer is a very efficient electrical equipment without many moving parts inside. There are five important technical parameters which have to be understood to properly select, operate & maintain a transformer.

KVA: The apparent electrical load that a transformer can withstand is specified in KVA (**K**ilo **V**olt **A**mperes) and represents total connected load it can handle. If all machines – to which transformer feeds power – consumes 200 amperes at 415V AC, transformer rating will be 83KVA (415 x 200 / 1000). Normally 20% safety factory is added to compensate for start-up current and overload conditions. If there are plans to add more machines in future, KVA (1 KVA = 1000VA) rating of expected machineries should also be considered since transformer is normally one time investment equipment. Alternatively, two or more transformers, even with different KVA ratings, can be connected in parallel to handle increased additional loads. The transformers will have an ability to withstand 20% overload for long periods of time, usually up to eight hours. Overloading beyond the rated load will result in severe voltage drop, deterioration of winding insulation and degradation of transformer oil.

Winding Type: The type of winding on HT & LT side will be decided by load & voltage pattern of equipments connected to the transformer. DyN-1 & DyN-11 are the most used methods of winding the HT transformer. They are called vector phasing of windings and the most commonly used is DyN-11 which means the HT side connection is DELTA type WITHOUT neutral and LT side connection is STAR type with NEUTRAL drawn out. Number 11 denotes that the LT side is LEADING by 30°. DyN-11 means same winding connection except that the LT side is in phase with HT side. We will not dig too much into the details in this newsletter. Most of the conventional & commercial step-down transformers are DyN-11 type.

Figure 2



Oil Type & Cooling: The complete core & winding assembly is enclosed in a leak-proof housing and will be filled with special oil, whose primary purpose is to remove "heat" generated during operation. The hot oil circulates thru "cooling coils or fins" due to its temperature difference and the cycle continues. Refer Figure-2 for details. Depending on the location and rating of transformer the oil can be cooled by natural air or other sources. The type of oil used and cooling method followed will be mentioned on nameplate, by four letters.

- First letter represents type of oil used
  - "O" denotes mineral or synthetic insulating liquid with fire point < 300°C (< 572°F)
  - "K" denotes insulating liquid with fire point > 300°C (> 572°F)
  - "L" denotes insulating liquid with no measurable point (usually very high)
- Second letter represents cooling mechanism for internal cooling medium
  - "N" denotes natural flow through cooling equipment & in the windings
  - "F" denotes forced circulation of oil using an external pump through the cooling fins

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- "D" denotes forced circulation of oil using an external pump through the cooling fins AND pushed into the transformer windings

- Third letter represents the external cooling medium
  - "A" denotes natural air
  - "W" denotes water
- Fourth letter represents circulation mechanism for external cooling medium
  - "N" denotes natural convection
  - "F" denotes forced circulation of air using fans or water using pumps

Most of the outdoor mounted transformers have "**ONAN**" type of cooling which is a combination of the parameters mentioned above (refer to the highlighted text). Any type of combination is possible based on transformer application. Usually, outdoor transformer will make optimum utilization of natural air for cooling, whereas indoor transformers use forced circulation for better cooling. Small table beside shows other possible combinations of cooling.

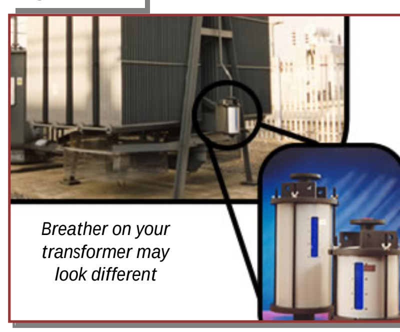
ONAF	OFAF	ODAF	OFWF	ODWF

Oil temperature should not exceed 75°C under normal operating conditions. A gauge will be fitted on the transformer housing or on conservator, indicating the oil temperature. A daily record (or observation) of this parameter will help in diagnosing any abnormalities before a breakdown can occur.

The oil properties will be checked according to IS: 335-1963 (Indian Standards) or BS: 148-1959 (British Standards). One of the most important properties of oil is its insulation resistance. It should withstand 40,000 Volts (40KV) for one minute. This check must be done after every filtration carried out on transformer.

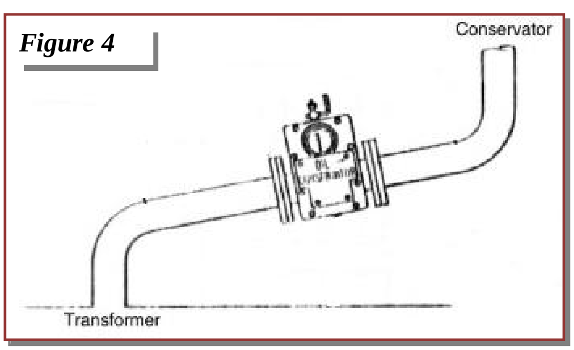
Normally, all oil-cooled transformers above 50KVA have a "conservator" (or reservoir) fitted on it which serves dual objectives of removing any air trapped inside the oil and maintaining constant oil pressure. The change of oil level in conservator indicates variation in oil's temperature. A silica-gel filled breather will be fitted to the conservator to help oil expand and contract as the temperature changes. IF SILICA GEL IS NOT PRESENT OR THE BREATHER GLASS IS BROKEN, AIR & MOISTURE WILL ENTER THE OIL (Especially in rainy season for outdoor mounted transformers) DETERIORATING TRANSFORMER PERFORMANCE. Ensure to keep the breather in good condition. It is a simple, but important component of transformer.

Figure 3



Buchholz Relay: Any abnormalities in the transformer induce a chemical reaction in the oil which in turn releases gases. Insulation failure, damage to internal parts, Excessive contamination, decomposition, air or moisture mixing, using old or recycled oil and reduction in quantity due to leakage are some of the common causes leading to release of gases transformer failure. Buchholz relay is a gas-actuated protective device that will be fitted to piping between transformer housing & oil conservator. This relay will sense the variation in gas pressure and activates two mercury switches in two stages.

Figure 4



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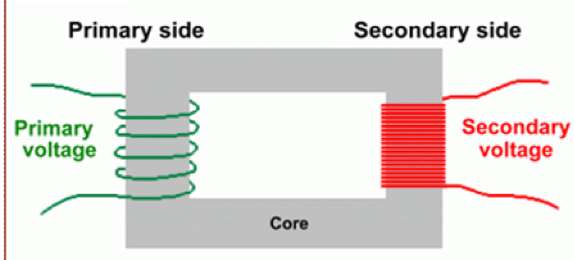
In first stage, it indicates a minor fault. In second stage, it indicates a major fault. Auxiliary contacts close when the fault occurs. These contacts can be used for an external alarm indication or disconnecting the main circuit breaker. These relays are usually sold as optional item and needs to be purchased separately. It is a wise investment for protecting the transformer from unforeseen and major breakdowns due to unattended deterioration of oil properties. A white gas indicates insulation material failure. Yellow gas indicates failure in other parts and white-black or grey gas indicates oil deterioration.

Voltage Control: The transformer works on principle of electromagnetic induction and does not have many moving parts. Number of conductor windings in primary & secondary determine the magnitude of voltage reduction (or increase). Hence, the secondary voltage changes whenever primary voltage level fluctuates. It is typical of state electricity to have various voltage levels in different parts of the day. An 11,000 volt line can measure 10,000 in the morning and can escalate to 12,000 volts in the middle of the night.

Figure 5 **A Transformer**



Secondary voltage can be altered by changing the winding ratio and try to keep it at an acceptable level. This is because of proportional relation that exists between windings and voltage level. This method of moderating primary winding to maintain almost stable secondary voltage is done by TAP CHANGING. There are two methods of changing the tap on a transformer.

OFF-LOAD TAP CHANGING – In this method, entire load on transformer is disconnected and using a hang-operated self-locking knob, the tap position is changed for required voltage. Usually there are five tap change positions on a standard transformer. Position 1 has highest winding ratio and gives least voltage on secondary side. Position 5 has lowest winding ratio and hence gives highest voltage on secondary side. This is the most simple and economical method of controlling voltage and is supplied as standard on many transformers.

Since measuring high voltage is cumbersome & risky, an ordinary multi-meter can be used to measure secondary voltage. Adjust the tap until secondary voltage is within acceptable limits. Below or above certain limits of high voltage variation, tap changing will not be able to regulate the secondary voltage. Transformer is NOT a voltage stabilizer and tap changing is only done within certain limits between certain fixed points and not continuously.

ON-LOAD TAP CHANGING (OLTC) – If the high-voltage side has frequent voltage fluctuations due to various reasons, it is not practical to shutdown all the loads and keep changing the winding ratio. On load tap changing system solves this problem by incorporating a closed loop motorized control which automatically modulates the winding ratio without disconnecting the load. A separate control system comprising 3-phase AC (or DC) motor, voltage sensors, protective relay will control the tap changing system of the transformer automatically. OLTC system is expensive and needs some attention, maintenance during operation and hence should not be installed just for the sake of it. Also if your unit has possibilities of connecting transformers in parallel in future, OLTC may become a limitation, since it has to be installed on every transformer and the control system can become very complicated to operate. Proper judgment is essential before deciding to install OLTC on your transformer.

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Tip for this newsletter

For instance if a manufacturing unit has combination of machines which are not so sensitive and sensitive to voltage fluctuations, a thumb rule can be followed to decide on installing OLTC. If the ratio of sensitive to total machines is more than 50% then OLTC is recommended. If the ratio is less than 50%, it is suggested to install stabilizers for sensitive machines. This works out economical from cost calculation as well.

Short descriptions of few other points about transformer are given below. A regular and proper care will go a long way in maintaining transformer & its components in top condition.

Indoor or Outdoor – This will decide type of cooling, cabling required for installation

- Cable entry – Top mounted or inside the box (both HT & LT)
- Grounding (earth) – Proper earthing of the transformer body is extremely essential to discharge any static charges developed in the oil and to protect transformer
- Oil testing – Yearly testing of oil parameters will reveal any abnormalities in the transformer. The minimum routine includes filtration, checking of insulation resistance, moisture content and viscosity inspection.
- Loose connections – All transformer connections – HT & LT – must be crimped and tightened properly to avoid sparks which will spoil the contacts & result in forced burning of fuses
- Like any other electrical equipment, transformer should also be loaded close to 80% for optimum efficiency & proper oil circulation

The "inside" story of transformer:

The fundamental principle behind many of electrical equipments, including transformer is electromagnetic induction. In very simple words, without breaking our valuable head on deep scientific theories, electromagnetic induction can be considered as a combination of three elements: "Electro," "Magnetic," & "Induction." An "electrical" voltage when passed thru a conductor produces a "magnetic" field which in turn creates an "induction" in any nearby conductor(s). In our beautiful school days, we have been taught that when a piece of iron is kept near a magnet for long time, it also becomes a magnet but with different strength.

In a transformer, the 11,000 (or 33, 000) AC volts passes thru primary winding, producing a strong magnetic field in the core. The magnetic field of core induces voltage in secondary winding and the magnitude of voltage generated is decided by the "winding ratio," ($V_{primary}$ / $V_{seconary}$ = $N_{primary}$ / $N_{secondary}$) although there many other technical factors involved. To visualize this in mechanical world – which is more "visible" to our eyes – consider two differently sized gears coupled together as windings. Refer Figure-6 for analogy. Please refer to Figure-5 for basic winding illustration of transformer. The small gear indicates high voltage (11 or 33 000 volts) with low current rating. It is coupled to a larger gear (secondary winding) which will have a reduced speed (voltage) at a high current. In either way, the total "power" that is "exchanged" remains unchanged.

Similarly, the KVA rating of a transformer remains constant. For example, in a 500 KVA transformer, the current on secondary at 415 AC at full load will be around 1200 amperes. And, on primary side, the current will be around 45 amperes. Since the current carried on high voltage lines are less than primary side, the cable sizes will be small as you can see on all HT transmission lines.

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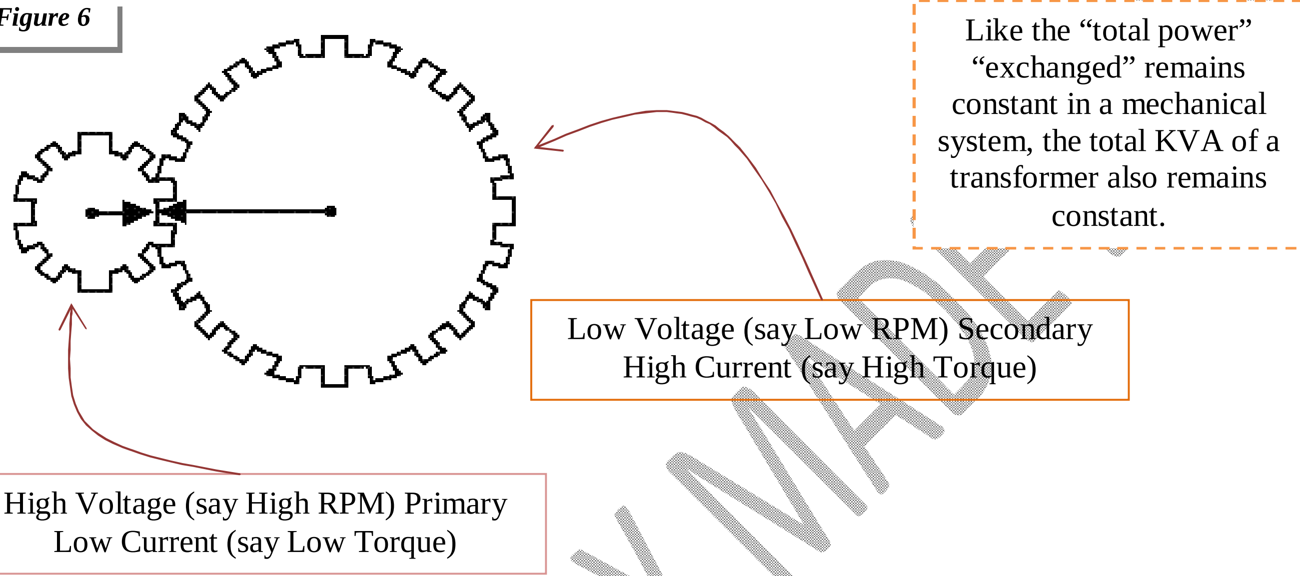
Latest technological advancements have resulted in "oil-free" transformers which can be mounted on roof-top of buildings or any well ventilated place and does not occupy much space. They eliminate all the complications of handling many of oil and oil related components, but come with an increased price tag at this point of time. These types of transformers are useful in places with shortage of allocating separate space for transformer like commercial buildings, IT parks.

Figure 6



A GOS – **G**ang **O**perating **S**witch – with pole (call it DP or Double Pole structure) is the most elementary protective element that should exist on the HT side. It is very normal to replace the GOS fuse with "some" piece of metal wire if it burns due to whatever reason. Remember, the fuse, whether on HT or LT side, does NOT burn without a reason. The root cause of fuse failure must be eliminated at the earliest before making multiple replacements of wire. And, proper wire suitable for the rating must be selected for replacement.

Apart from the standard GOS, a HT fuse assembly with other accessories will also be installed for additional safety of transformer & proceeding machineries.

A well maintained transformer also improves "power factor" (PF or Cos-Φ) of the unit and reduces PF penalty imposed by state electricity board.

What lies next?

One of the easiest methods of understanding the invisible field of electrical concepts is to relate it to mechanical components. Soon, we will be publishing interesting article on this comparison.