

Practical applications of transformer



**ASSIGN
BUSTER**

Abstract- Generating power is possible in few stations. The power is generated then has to transmit to the various parts of the country. Large power should be transmitted on very high voltage to reduce the amount of copper material and increase the transmission efficiency. Hence the energy generated is transformed twice, thrice, or even four times before utilized. Such transformation of ac from one voltage to another is done by transformer.

DISCOVERY The phenomenon of electromagnetic induction was discovered by Michael Faraday and Joseph Henry in 1831. The relationship between electromotive force or voltage and magnetic flux was formalized in an equation now referred to as Faraday's law of induction. This law states that whenever there is a relative motion between the coil and magnet emf is induced in the coil. The induced emf lasts so long as magnetic flux linked with the coil changed. The induced emf is directly proportional to the time rate of change of magnetic flux linked with the coil.

Where, $\hat{I}B$ is the magnetic flux through the circuit.

Fig. 1: Faraday's experiment with induction between coils of wire

TRANSFORMER

A electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load.

Fig. 2: Structure of Transformer

PRINCIPLE The transformer is based on two principles: firstly, that an electric current can produce a induced magnetic field by varying with time and

secondly that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil. Changing the current in the primary coil changes the magnetic flux that is developed. The changing magnetic flux induces a voltage in the secondary coil. The voltage induced across the secondary coil may be calculated from Faraday's law of induction, which states that:

Where V_S is the instantaneous voltage, N_S is the number of turns in the secondary coil and \hat{i} equals the magnetic flux through one turn of the coil. If the turns of the coil are oriented perpendicular to the magnetic field lines, the flux is the product of the magnetic flux density B and the area A through which it cuts. The area is constant, being equal to the cross-sectional area of the transformer core, whereas the magnetic field varies with time according to the excitation of the primary. Since the same magnetic flux passes through both the primary and secondary coils in an ideal transformer, the instantaneous voltage across the primary winding equals. Taking the ratio of the two equations for V_S and V_P gives the basic equation for stepping up or stepping down the voltage.

CONSTRUCTION OF TRANSFORMER Steps are:

Coil Winding

Core Assembly

Core-Coil Assembly

Tank-up

Transformer Tank

Painting and Finishing

Fig. 3: Transformer showing each part

1. CONSERVATOR: a) Check the oil level in the conservator. If the level is low than the optimum mark indicated on the oil level gauge, it should be topped with proper grade of transformer oil having suitable breakdown voltage value.

b) The tightness of the cap/plug of the oil filler pipe, drain plug or drain valve should be checked. The oil level gauge of the conservator should always be kept clean so that the oil level is visible from a short distance.

Fig. 4: Conservator

2. BUCHHOLZ RELAY: a) the observation glasses should show that the buchholz relay is properly filled with oil. If necessary, bleeding can be done from the two cocks. The drain plug should be tight and no leaking should be there.

b) The cover on the connection chamber should be opened to observe whether connections are properly tight.

3. SHUT OFF VALVE: This should always be in fully open position while the transformer is being energized.

4. BREATHER: a) The plug at the end of the breather pipe is to be removed and breather fitted on to the pipe along with the fly nut.

b) It is necessary before fitting the breather to observe the color of the silica gel. If necessary, the breather should be opened and the silica gel properly dried up so that its color is perfectly bluish. c) The chamber at the bottom of the breather should be filled in with dry transformer oil up to the level marked.

Fig. 5: Showing Tank in oil

5. DIAL TYPE THERMOMETER: If it is provided with alarm and trip contacts, these should be set to proper temperature before energizing the transformer. For guidance purposes, it may be mentioned here that a transformer having temperature rise of 45/55°C, the trip contact should be set at ambient temperature plus 45°C and the alarm contact will be 5° - 10° prior to this.

6. WINDING TEMPERATURE INDICATOR: This will be set in the same way as the dial type thermometer excepting that the trip contact should be set at ambient temperature plus 55°C.

7. MARSHALLING BOX: The windows of the marshalling box should always be kept clean so that the readings of the oil temperature indicator and winding temperature indicator can be easily read from outside. Some dehydrating agent may be kept inside the marshalling box so that the box is kept always in dry condition. Do not keep the Dorr of marshalling box open. It must be locked.

8. EXPLOSION VENT: a) In case an equalizer pipe connection is provided, the valve in the pipe should be kept in open position before the transformer is

energized. b) If the explosion vent is provided with an air release device, this should be opened once to release any pressure generated inside and then it should be closed. c) The diaphragm of the vent should be intact.

9. BUSHINGS: To prevent sparking bushings are used when wires at low voltage and transformer's wire at high voltage are connected.

Fig. 6: Showing Bushings

10. COOLANT:

Fig. 7: Coolant High temperatures will damage the winding insulation. Small transformers do not generate significant heat and are cooled by air circulation and radiation of heat. Power transformers rated up to several hundred kVA can be adequately cooled by natural convective air-cooling, sometimes assisted by fans. In larger transformers, part of the design problem is removal of heat. Some power transformers are immersed in transformer oil that both cools and insulates the windings. The oil is a highly refined mineral oil that remains stable at transformer operating temperature. Indoor liquid-filled transformers must use a non-flammable liquid, or must be located in fire resistant rooms. Air-cooled dry transformers are preferred for indoor applications even at capacity ratings where oil-cooled construction would be more economical, because their cost is offset by the reduced building construction cost.

TYPES OF TRANSFORMER

1. ON THE BASIS OF TRANSFORMATION RATIO: A) Step-up transformers

A “ step-up transformer” allows a device that requires a high voltage power supply to operate from a lower voltage source. The transformer takes in the low voltage at a high current and puts out the high voltage at a low current. Transformers only work with alternating current. Using direct current will create a magnetic field in the core but it will not be a changing magnetic field and so no voltage will be induced in the secondary coil. Using a step up transformer to increase the voltage does not give you something for nothing. As the voltage goes up, the current goes down by the same proportion. The power equation shows that the overall power remains the same.

$$P = V \times I \text{ Power} = \text{Voltage} \times \text{Current}$$

Fig. 8: Step up Transformer

Electricity is first produced at the power plants. Electricity is then sent to step-up transformers where low-voltage electricity is changed to high voltage to facilitate the transfer of power from the power plant to the customer. Voltage must be increased so that the electric current has the “ push” it needs to efficiently travel long distances. From the step-up transformer, transmission lines carry the high voltage electric current long distances through thick wires mounted on tall towers that keep the transmission lines high above the ground. Insulators made of porcelain or polymers are used to prevent the electricity from leaving the transmission lines.

B) Step-down transformers

A “ step-down transformer” allows a device that requires a low voltage power supply to operate from a higher voltage. The transformer takes in the

high voltage at a low current and puts out a low voltage at a high current. A step down transformer has less turns of wire on the secondary coil, which makes a smaller induced voltage in the secondary coil. It is called a step down transformer because the voltage output is smaller than the voltage input. If the secondary coil has half as many turns of wire then the output voltage will be half the input voltage. Decreasing the voltage does not decrease the power. As the voltage goes down, the current goes up.

Fig. 9: Step Down Transformer

2. ON THE BASES OF WINDINGS:

A) Core type transformer:

Fig. 10: Core Transformer

B) Shell type transformer:

Fig. 11: Shell type transformer

3. ON THE BASES OF SERVICE: A) Power transformer: Power transformers are used in transmission network for voltage ratings of (440kv, 220kv, 110kv, 66Kv) and are generally rated above 200MVA. Power transformer generally operated at full load. Hence, it is designed such that copper losses are minimum. B) Distribution Transformers: Distribution Transformers are used in (33 kV, 11kv, 6. 6 kV) voltage levels in Distribution network and are generally rated less than 200 MVA. A distribution transformer is always online and operated at loads less than full load for most of time. Hence, it is designed such that core losses are minimum.

IDEALTRANSFORMER The idealizations are as follows: 1. Magnetic circuit is linear and has infinite permeability. The consequence is that a vanishingly small current is enough to establish the given flux. Hysteresis loss is negligible. As all the flux generated confines itself to the iron, there is no leakage flux.

2. Windings do not have resistance. This means that there are no copper losses, nor there

is any ohmic drop in the electric circuit.

LOSSES IN TRANSFORMER

An ideal transformer would have no energy losses, and would be 100% efficient. In practical transformers energy is dissipated in the windings, core, and surrounding structures. Larger transformers are generally more efficient, and those rated for electricity distribution usually perform better than 98%.

All transformers have copper and core losses.

1. Copper loss:

Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings. Copper loss, in watts.

Copper Loss $I_1^2 R_1 + I_2^2 R_2$

Where I_1 = primary current

I_2 = secondary current

<https://assignbuster.com/practical-applications-of-transformer/>

RP = primary winding resistance

RS = secondary winding resistance

2. Core loss:

A) Hysteresis losses

Each time the magnetic field is reversed, a small amount of energy is lost due to hysteresis within the core. For a given core material, the loss is proportional to the frequency, and is a function of the peak flux density to which it is subjected.

B) Eddy currents

Ferromagnetic materials are also good conductors, and a solid core made from such a material also constitutes a single short-circuited turn throughout its entire length. Eddy currents therefore circulate within the core in a plane normal to the flux, and are responsible for resistive heating of the core material. The eddy current loss is a complex function of the square of supply frequency and inverse square of the material thickness.

Mechanical losses

In addition to magnetostriction, the alternating magnetic field causes fluctuating electromagnetic forces between the primary and secondary windings. These incite vibrations within nearby metalwork, adding to the buzzing noise, and consuming a small amount of power.

Stray losses

Leakage inductance is by itself largely lossless, since energy supplied to its magnetic fields is returned to the supply with the next half-cycle. However, any leakage flux that intercepts nearby conductive materials such as the transformer's support structure will give rise to eddy currents and be converted to heat. There are also radiative losses due to the oscillating magnetic field, but these are usually small.

EFFICIENCY

WHAT CAUSE LOSSES

1. Due to the large value for the permeance ($\hat{\mu}_r$ of the order of 1000 as compared to air) the magnetizing current requirement decreases dramatically. This can also be visualized as a dramatic increase in the flux produced for a given value of magnetizing current.
2. The magnetic medium is linear for low values of induction and exhibits saturation type of non-linearity at higher flux densities.
3. The iron also has hysteresis type of non-linearity due to which certain amount of power is lost in the iron (in the form of hysteresis loss), as the B-H characteristic is traversed.
4. Most of the flux lines are confined to iron path and hence the mutual flux is increased very much and leakage flux is greatly reduced.
5. The flux can be easily 'directed' as it takes the path through steel which gives great freedom for the designer in physical arrangement of the excitation and output windings.

6. As the medium is made of a conducting material eddy currents are induced in the same and produce losses. These are called 'eddy current losses'. To minimize the eddy current losses the steel core is required to be in the form of a stack of insulated laminations.

APPLICATION OF TRANSFORMER

1. Instrument transformers

Instrument transformers comprise a large category of current and potential transformers for various voltage, frequency and physical size ranges. We have broken them up into several different groupings: low voltage, which are system voltages under 15kV; high frequency, operating frequency over 1kHz; and size ranges from board mount parts up to current transformers with window sizes of 254mm by 610mm. Read through the different types we supply below and use our Instrument

Fig. 12: Instrument transformer

2. Potential Transformers:

Used primarily in a step down environment to monitor voltage. They are designed for connection line-to-line or line-to-neutral in the same manner as ordinary voltmeters. The secondary voltage bears a fixed relation with the primary voltage so that any change in potential in the primary circuit will be accurately reflected in the meters or other devices connected across the secondary terminals. Potential transformers can be used with voltmeters for voltage measurements or they can be used in combination with current transformers for watt-meter or watt-hour meter measurements. They are

<https://assignbuster.com/practical-applications-of-transformer/>

used also to operate protective relays and devices, and for many other applications, Since they are used in a monitoring capacity, they generally require much greater accuracy in design.

Fig. 13: Potential transformer

3. Metering Toroidal Current Transformers:

Traditional, window type current transformers for measuring 50-400HZ currents of 5A to 15000A with secondaries of 0. 1A, 1A and 5A (special secondary currents are available). Burden: B 0. 1 through 1. 8 (2. 5VA to 50 VA) with Accuracy class: 0. 2 to class 5. 0 as per IEC 185 or class 0. 3, 0. 6 or 1. 2 as per ANSI C 57. 13. Inside diameters of up to 8. 00". Many models are available as U. L. recognized devices. Applications include:

- UPS systems
- Transfer switches
- Motor-generator sets
- Commercial sub-metering,
- 3 CT ' s in one package for 3-phase metering
- Accurate measuring for metering/WATT/VAR
- Current sensing, recording, monitoring & control
- Control panels and drives
- Standard CT used as measuring standard for comparison

- Winding temperature indicator (WTI) for power transformers
- Summation current transformers.

Fig. 14: . Metering Toroidal Current Transformers

Large Frame Current Transformers For measuring 50-400HZ currents in bus bar and other large conductor systems. Typical configuration is 400A to 12000A primary current with secondary of 1A or 5A Inside areas as small as 3. 00" X 7. 00" and as large as 7. 00" X 27. 00" and 10. 00"

X 24. 00". All models are available with optional mounting plates for " bulk-head" mounting. Some models are U. L. recognized devices.

4. Split-Core Current Transformers

This type of current transformer is available to measure AC currents from 100A to 600A, at 50 to

400HZ. They are very popular in sub-metering applications where existing systems are being upgraded and it is impractical to isolate the primary conductor. It is even possible to install this type of transformer while the conductor is energized, however it is paramount that certain safety precautions be followed under such conditions. Rectangular in shape, standard split-core models are available with window dimensions up to 4. 00" X 7. 50". Even larger, custom designed sizes are available by special order. Secondary ratings of 5A, 1A, and 100ma are all common in split-core current transformers. Two model groups are available, SP and SPS. The former is provided with a

stainless steel screw-clamp band securing the two core halves; the latter has a UV resistant nylon band. All ratios are available in either type. Electrical and magnetic performance is identical for the two groups.

Fig. 15: Split-Core Current Transformers

5. Miniature Current Transformers

These are constructed using one of the following methods: Plastic casing, Resin casted, Resin

dipped, Tape insulated,. Typical turns ratio: 4000 : 1 to 500 : 1 and Accuracy: Class 0. 1 to Class

Applications include:

Fig. 15: Split-Core Current Transformers

- Energy meters for accurate current measurement
- Current control
- Current signature of motors
- Load sensing
- Ground fault sensing
- Monitoring of process parameters
- AC level to logic conversation & bar graph
- As a transducer in instrumentation

6. Relay Class Protection Current Transformers

This type of CT includes oil-immersed bussing and Resin molded versions.

Primary current range from 5 Amp to 5000 Amp with secondary current 5A,

1A , or 0.1 A. Typical Burden B 0.1 through

B 4.0 (2.5VA to 50 VA & more) and Accuracy Class As per ANSI C 57.13 and

IEC 185. Applications include:

- Protection relays/Relay panels
- Earth fault protection
- Bussing type, oil-immersed CT in power transformer
- Control panes and switch boards
- Air/Gas circuit breakers
- Motor control cubicles
- Power control centers
- Bus bar protection systems
- Differential protection systems

Fig. 16: Relay Class Protection Current Transformers

7. Medium voltage Instrument Transformers

These are used with a system voltage 3.3kV to 25kV and BIL 4.5 to 125 full wave crest kV. They are reliably constructed using vacuum cast with epoxy

<https://assignbuster.com/practical-applications-of-transformer/>

resin/polyurethane resin and are able to withstand heavy fault conditions but are not made for exposure to sunlight.. Single CT's can be built with multiple cores; for example – one for measuring and another for relaying are possible. Also multitap secondaries can be provided (up to 4). Typical primary current 5 Amp to 3000 Amp and secondary current 5A/1A/01. A. Applications include:

- Metering and Relaying
- Energy meter panels
- Medium voltage switch gears and control panels
- Medium voltage circuit breakers
- Motor Control Panels

Fig. 17: Medium voltage Instrument Transformers

8. PC mount 50 to 400Hz Current Transformers

These offer a small footprint for the design engineer looking to sensor current on board. They can also be used for Metering Class (Burden from B 0. 1 to B 1. 8 with accuracy class from 0. 3 to 2. 4 as per customer requirement. (As per ANSI C 57. 13 and IEC 185) and for Relay Class Burden from B 1. 0 to B 4. 0 and relay voltage class from C 10 to C 400 or T200 as per customer requirement. (As per ANSI C 57. 13 and IEC 185) Secondary current range from 0. 1 to 5 amp. Typical constructions are plastic casing or resin molded. Applications include:

- Sensing current overload

- Ground fault detection

- Metering

PC mount 20kHz to 200kHz Current Transformers

These are used for measuring high frequency primary currents up to 15 Amps with primary to secondary isolated to 2500 VAC and have optimum performance over designated current and frequency ranges. Applications include:

- Isolated current feed-back signal in switch mode power

supplies

- Motor current load/overload

- Lighting

- Switch controls

- Ultra-sound current

- High resolution sonar current

- Isolated bi-directional current sensor with full wave bridge

Fig. 18: PC mount 50 to 400Hz Current Transformers

9. Air core transformers : Another kind of special transformer, seen often in radio-frequency circuits, is the air core transformer. (Figure below) True to its name, an air core transformer has its windings wrapped around a nonmagnetic form, usually a hollow tube of some material. The degree of coupling (mutual inductance) between windings in such a transformer is many times less than that of an equivalent iron-core transformer, but the undesirable characteristics of a ferromagnetic core (eddy current losses, hysteresis, saturation, etc.) are completely eliminated. It is in high-frequency applications that these effects of iron cores are most problematic.

Fig. 19: Air core transformers

Air core transformers may be wound on cylindrical (a) or toroidal (b) forms. Center tapped primary with secondary (a). Bifilar winding on toroidal form (b). The inside tapped solenoid winding, (Figure (a) above), without the over winding, could match unequal impedances when DC isolation is not required. When isolation is required the over winding is added over one end of the main winding. Air core transformers are used at radio frequencies when iron core losses are too high. Frequently air core transformers are paralleled with a capacitor to tune it to resonance. The over winding is connected between a radio antenna and ground for one such application. The secondary is tuned to resonance with a variable capacitor. The output may be taken from the tap point for amplification or detection. Small millimeter size air core transformers are used in radio receivers. The largest radio transmitters may use meter sized coils. Unshielded air core solenoid transformers are mounted at right angles to each other to prevent stray coupling. Stray coupling is

minimized when the transformer is wound on a toroid form. (Figure (b) above) Toroidal air core transformers also show a higher degree of coupling, particularly for bifilar windings. Bifilar windings are wound from a slightly twisted pair of wires. This implies a 1: 1 turns ratio. Three or four wires may be grouped for 1: 2 and other integral ratios. Windings do not have to be bifilar. This allows arbitrary turns ratios. However, the degree of coupling suffers. Toroidal air core transformers are rare except for VHF (Very High Frequency) work. Core materials other than air such as powdered iron or ferrite are preferred for lower radio frequencies.

10. Tesla Coil: One notable example of an air-core transformer is the Tesla Coil, named after the Serbian electrical genius Nikola Tesla, who was also the inventor of the rotating magnetic field AC motor, polyphase AC power systems, and many elements of radio technology. The Tesla Coil is a resonant, high-frequency step-up transformer used to produce extremely high voltages. One of Tesla's dreams was to employ his coil technology to distribute electric power without the need for wires, simply broadcasting it in the form of radio waves which could be received and conducted to loads by means of antennas. The basic schematic for a Tesla Coil is shown in Figure below.

Fig. 20: Tesla coil

Tesla Coil: A few heavy primary turns, many secondary turns.

The capacitor, in conjunction with the transformer's primary winding, forms a tank circuit. The secondary winding is wound in close proximity to the primary, usually around the same nonmagnetic form. Several options exist

for “ exciting” the primary circuit, the simplest being a high-voltage, low-frequency AC source and spark gap: (Figure below)

System level diagram of Tesla coil with spark gap drive. The purpose of the high-voltage, low-frequency AC power source is to “ charge” the primary tank circuit. When the spark gap fires, its low impedance acts to complete the capacitor/primary coil tank circuit, allowing it to oscillate at its resonant frequency. The “ RFC” inductors are “ Radio Frequency Chokes,” which act as high impedances to prevent the AC source from interfering with the oscillating tank circuit. The secondary side of the Tesla coil transformer is also a tank circuit, relying on the parasitic (stray) capacitance existing between the discharge terminal and earth ground to complement the secondary winding’s inductance. For optimum operation, this secondary tank circuit is tuned to the same resonant frequency as the primary circuit, with energy exchanged not only between capacitors and inductors during resonant oscillation, but also back-and-forth between primary and secondary windings. Tesla Coils find application primarily as novelty devices, showing up in high school science fairs, basement workshops, and the occasional low budget science-fiction movie. It should be noted that Tesla coils can be extremely dangerous devices. Burns caused by radio-frequency (“ RF”) current, like all electrical burns, can be very deep, unlike skin burns caused by contact with hot objects or flames. Although the high-frequency discharge of a Tesla coil has the curious property of being beyond the “ shock perception” frequency of the human nervous system, this does not mean Tesla coils cannot hurt or even kill you! I strongly advise seeking the

assistance of an experienced Tesla coil experimenter if you would embark on building one yourself.

11. Linear Variable Differential Transformer: A linear variable differential transformer (LVDT) has an AC driven primary wound between two secondary's on a cylindrical air core form. A movable ferromagnetic slug converts displacement to a variable voltage by changing the coupling between the driven primary and secondary windings. The LVDT is a displacement or distance measuring transducer. Units are available for measuring displacement over a distance of a fraction of a millimeter to a half a meter. LVDT's are rugged and dirt resistant compared to linear optical encoders.

Fig. 21: LVDT

The excitation voltage is in the range of 0.5 to 10 VAC at a frequency of 1 to 200 KHz. A ferrite core is suitable at these frequencies. It is extended outside the body by a non-magnetic rod. As the core is moved toward the top winding, the voltage across this coil increases due to increased coupling, while the voltage on the bottom coil decreases. If the core is moved toward the bottom winding, the voltage on this coil increases as the voltage decreases across the top coil. Theoretically, a centered slug yields equal voltages across both coils. In practice leakage inductance prevents the null from dropping all the way to 0 V. With a centered slug, the series-opposing wired secondary's cancel yielding $V_{13} = 0$. Moving the slug up increases V_{13} . Note that it is in-phase with V_1 , the top winding, and 180° out of phase with V_3 , bottom winding. Moving the slug down from the center position increases V_{13} . However, it is 180° out of phase with V_1 , the top

<https://assignbuster.com/practical-applications-of-transformer/>

winding, and in-phase with V3, bottom winding. Moving the slug from top to bottom shows a minimum at the center point, with an 180° phase reversal in passing the center.

Acknowledgment