Province of the
EASTERN CAPE
EDUCATION

DIRECTORATE SENIOR CURRICULUM MANAGEMENT (SEN-FET)

HOME SCHOOLING SELF-STUDY WORKSHEET

SUBJECT	**ELECTRICAL TECH. (POWER SYSTEMS)**	**GRADE**	12	**DATE**	APRIL 2020
TOPIC	**TRANSFORMERS NOTES**	**TERM 1 REVISION**	( )	**TERM 2 CONTENT**	(√)
TIME ALLOCATION		**TIPS TO KEEP HEALTHY**			
INSTRUCTIONS	NOTES ON THREE PHASE TRANSFORMERS	1. **WASH YOUR HANDS** thoroughly with soap and water for at least 20 seconds. Alternatively, use hand sanitizer with an alcohol content of at least 60%. 2. **PRACTICE SOCIAL DISTANCING** – keep a distance of 1m away from other people. 3. **PRACTISE GOOD RESPIRATORY HYGIENE**: cough or sneeze into your elbow or tissue and dispose of the tissue immediately after use. 4. **TRY NOT TO TOUCH YOUR FACE.** The virus can be transferred from your hands to your nose, mouth and eyes. It can then enter your body and make you sick. 5. **STAY AT HOME.**			

ELECTRICAL TECHNOLOGY – POWER SYSTEMS

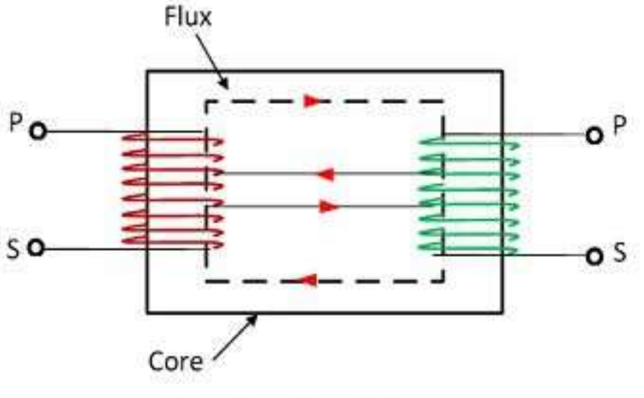
GRADE 12

THREE-PHASE TRANSFORMERS

Introduction

	A transformer is a device that changes ac electric power at one voltage level to ac electric power at another voltage level through the action of magnetic field.	

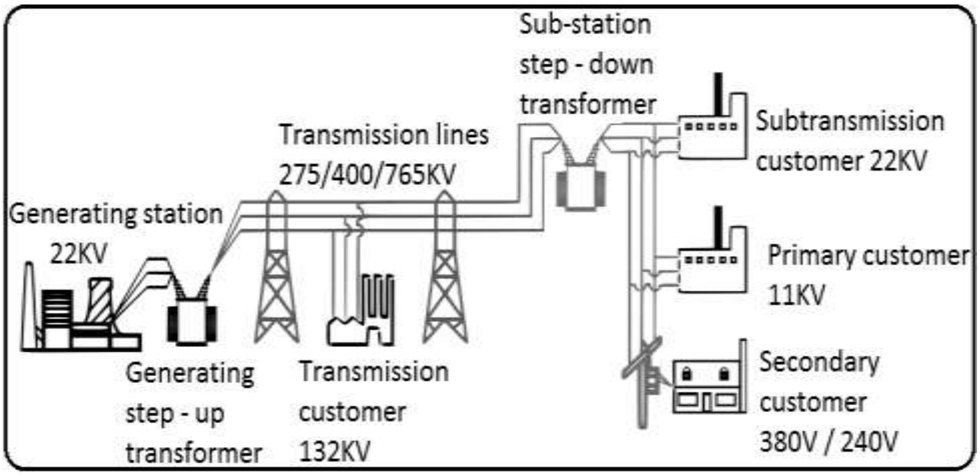
There are two or more stationary electric circuits that are coupled magnetically.



Core Type Transformer

Circuit Globe

It involves interchange of electric energy between two or more electric systems.
Transformers provide much needed capability of changing the voltage and current levels easily.



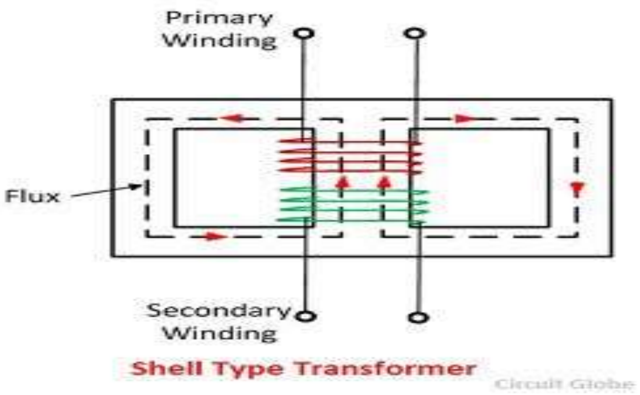
- They are used to step down or step up (transform) the voltage in a distribution network to the required value
- To transfer power from one ac circuit to another, with a change of voltage and corresponding current flow
- To isolate one circuit from another electrically

PRINCIPLE OF OPERATION AND CONNECTIONS

Operation:
When an alternating voltage is applied to the primary windings an alternating flux is created in the windings

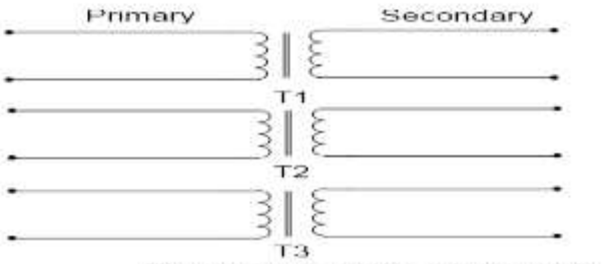
This flux will link the secondary windings through the magnetic path of the iron core of the transformer inducing in it an emf of the same frequency.

Connections



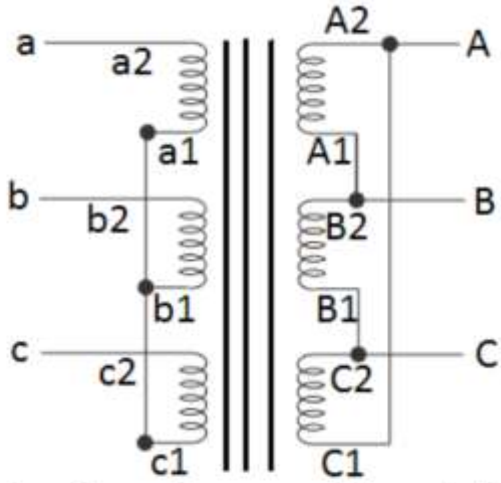
Shell Type Transformer

A transformer has **two coils** or **windings** namely the primary winding and secondary winding. These two windings are placed on the same core. The incoming winding called **primary winding** is connected to the ac supply line and the output coil called the **secondary winding** connected to the load.



Three single phase transformers

Three individual single-phase transformers can be connected together to form a single three-phase transformer.



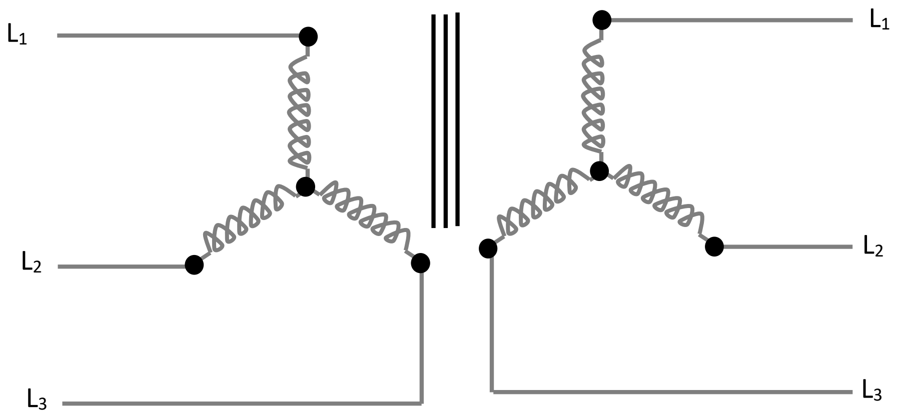
A star/delta transformer by means of three single phase transformers

A single three-phase unit consists of three single phase windings inside a single tank and forms a complete unit. For the operation of such a **three phase-transformer** the **three pairs of windings or single-phase transformers** must be **identical** in the following characteristics:

- Size
- Frequency
- Windings ratio
- Voltage
- Current
- Power
- Power factor
- Efficiency.

The three primary windings and three secondary windings of a three-phase transformer can be connected together in four different ways to form a single unit. These combinations are delta-to-star, star-to-delta, delta-to-delta and star-to-star.
Note: For brevity a star connection will be indicated with a “Y” or sometimes with “wye” and a delta connection with a
The **four inter-connected combinations** can be written as:

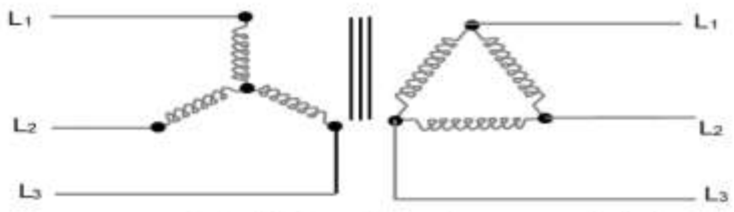
- **Star/Star (Y/Y)**: It is not used a lot due to harmonics present in the secondary. It is used mainly for **interior wiring of premises**.



star / star transformer by means of single three phase transformer

Star-Star transformers are formed by connecting one terminal of each phase of the primary windings to the common point, called the neutral point. The same connections are done on the secondary side.

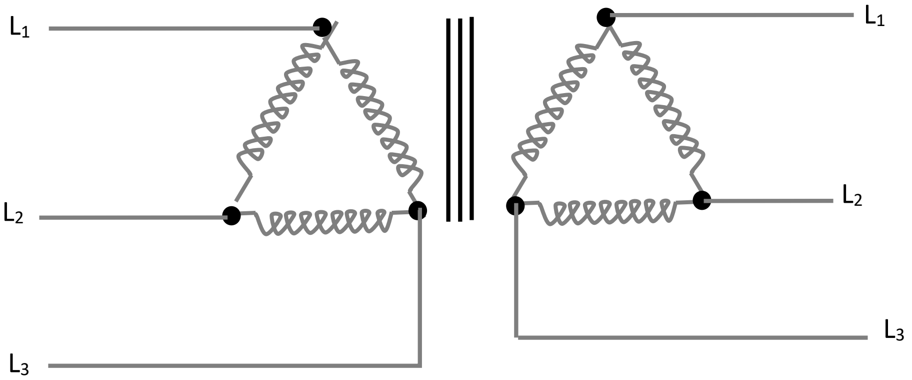
- **Star/Delta (Y/ Δ):** It is used as **a step down transformer in high voltage supply lines.**



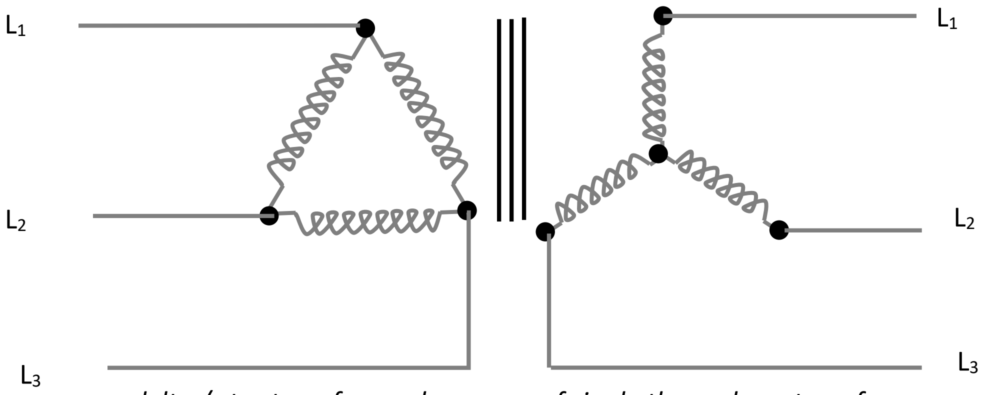
star / delta transformer by means of single three phase transformer

Star-Delta transformers are formed by connecting the primary side in star as described in star-star connection, and the secondary side as a triangular loop (delta connection).

- **Delta/Delta (Δ/Δ**): It is used mainly in **heavy industries where a high power transfer is essential.**



delta / delta transformer by means of single three phase transformer



delta / star transformer by means of single three phase transformer

Delta-Delta transformers are formed by connecting the three primary phases in series to form a closed triangular loop. The same connections are done on the secondary side.

- **Delta/ Star (Δ /Y):** It is used extensively as **step down transformers in distribution systems where a four-wire system is require**d.

Delta-Star transformers are formed by connecting the primary side in delta or triangular loop and the secondary side windings are connected to a common point, called the neutral point.

CONCEPT OF LOSSES

Losses that occur in a three-phase transformer are the same as that of the single-phase transformer. Types of losses that occur in transformers are **I^2R or copper loss, hysteresis and current losses**. If heat is not dissipated properly, the temperature of the transformer will rise continually and cause a continual degradation of its insulation system. It is essential to control the temperature within permissible limits to ensure the long working life of the transformer.

Factors that can contribute to excessive heating:

- Constant overloading
- Insufficient ventilation
- Transformer oil may be impure due to carbonization
- Transformer oil may be insufficient

Comparison of single phase and three-phase transformers:

SINGLE PHASE TRANSFORMERS	THREE-PHASE TRANSFORMER
More expensive.	Cheaper.
Uses two windings.	Three windings space apart by 120°.
Instantaneous power is sinusoidal.	Continuous power.
Size of metal quantity the same.	Size of metal quantity the same.
Conductor size bigger than for three-phase.	Conductor size 75% of that needed for single phase.
Lower efficiency than three-phase.	Higher efficiency than single phase.
Higher loss	Losses minimum.
Used in most homes in South Africa.	Used in larger businesses, as well as industry and manufacturing.
Able to supply ample power for smaller customers, including homes and small, non-industrial businesses.	Increasingly popular in power-hungry, high-density data centres.
Adequate for running motor up to 5 horsepower; a single-phase motor draws significantly more current than the equivalent three-phase power a more efficient choice for industrial application.	Expensive to convert from an existing single-phase installation, but 3-phase allows for smaller, less expensive wiring and lower voltages, making it safer and less expensive to run.
Cannot be used on three-phase equipment.	Highly efficient for equipment designed to run on three-phase.

CONSTRUCTION OF THREE-PHASE TRANSFORMERS

A three-phase transformer is basically three interconnected single-phase transformers on a single laminated core. The windings must be connected in a proper sequence in order to match the incoming power and therefore transform the incoming voltage level needed in the proper phasing sequence or polarity.
The transformers are put into an enclosure which is filled with dielectric oil which provides electrical insulation between the windings and the

case and also provides cooling and prevents the formation of moisture on the windings.
There are **two types of transformer construction available**, namely, the **core-type and shell-type transformers**. The **core-type transformer** consists of **three legs or limbs** and is the most common type. The **shell-type transformer** consists of **five legs or limbs**.

Comparison between the core-type and shell-type transformers

Core-type transformers	**Shell-type transformers**
The core is enclosed	The windings are enclosed
Coils are wound around all three core legs.	Coils are wound around the central section of the core.
Windings hide the core limbs but are well visible.	Core hides the major part of the windings.
Axis of the core type windings is normal vertical.	Axis of the shell-type windings can be horizontal or vertical.
Core-type is the most commonly used method of construction. Smaller core means less weight and expense.	Shell-type transformer is considered the most efficient and is used for larger transformers as the height can be reduced.
Coils can be easily removed for maintenance.	Large number of laminations must be removed for maintenance.
Core has three limbs.	Core has five limbs.
Used in low voltage transformers.	Used in high voltage transformers.
Single magnetic circuit.	Double magnetic circuits.

Application of transformers

1. The main function of a transformer is to step up and step down the voltage.
2. Low power three-phase transformers are normally used in industrial operations and low voltage domestic distribution systems.
3. Single and three-phase are supplied to commercial sites, shopping malls and light industries.
4. Some domestic installations require single and three-phase systems.
5. Three-phase transformers are used exclusively in distribution networks.
6. Large factories normally receive three-phase electricity. They convert it themselves to lower voltages and single-phase where required.

Cooling

If heat generated in a transformer is not dissipated properly, the excess temperature in a three-phase transformer may cause serious problems like insulation failure. Then it's obvious that transformers need a cooling system. Transformers can be divided into two types, namely:

- dry transformers or
- oil immersed transformers.

Dry transformer is a transformer without oil, for heat to be dissipated dry transformers are equipped with tubular radiator around which air circulates.

Cooling methods for **dry type transformers** are:

- Air Natural (AN), Up to 3 MVA.
- Air Forced (AF), Up to 15 MVA.

Magnetic circuit and windings of power transformers are usually mounted in a tank filled with mineral oil which is used to insulate and cool the windings.

Cooling methods for **oil immersed transformers** are:

- Oil Natural, Air Natural (ONAN), Up to 30 MVA.
- Oil Natural, Air Forced (ONAF), Up to 60 MVA.
- Oil Forced, Air Forced (OFAF), Power stations and substations.
- Oil Forced, Water Forced (OFWF)". Very large transformers, in several hundreds of MVA. Heated water is taken away to cool in separate cooling towers.

SAFETY

Safety in the workshop is utmost important. Working with transformers require the utmost care and strictly under supervision of the teacher. Adhere to the following additional safety instructions:

1. Exercise EXTREME CARE during the experiments.
2. Assemble or modify the circuit ONLY when the circuit breakers are off.
3. Use short wires where possible and ensure that the wires are not loosely connected.
4. Do not switch the circuit before the teacher has inspected it and is satisfied with it.
5. NEVER TOUCH ANY BARE ELECTRIC WIRE OR TERMINAL. You might just be going to get the biggest shock in your life.
6. Transformers heat up. After the practical wait for the transformer to cool down before returning it to the storeroom.
7. Be careful of the secondary terminals of a live open circuit transformer. You might become the load of the circuit.
8. The safety aspect of transformers is formulated by the following SANS documents:
    - SANS 780:2009: Distribution transformers

- SANS 60076-1
- SANS 61558-2-23:2000: Safety of Power Transformers, Power Supply Units.
- OHS act: Electrical machinery regulations 2011.

PROTECTION

In all protection schemes the cost has to be related to the cost of the equipment it is protecting. In specifying a scheme, the economic effect of the loss of the unit and the cost to repair a major breakdown should be taken into account.

There is a list of the most common INTERNAL failures of three-phase transformers, namely:

- Windings failures ±37%
- Tap changing failures ±22%
- Bushing failures ±11%
- Terminal board failures ±3%
- Core failures ±1%
- Other types of failures ±26%

The last item may include EXTERNAL conditions which could cause faults to develop and they are:

- Heavy through-faults
- Overloads
- Switching surges
- Lightning.

Protective devices will be briefly explained below. Any fault will activate these relays and isolate the transformer.

1. **Inverse Definite Minimum Time relay (IDMT relay):**

These relays are usually of the induction type with reverse definite-minimum time characteristics-means a severe overcurrent will have very short time to isolate the transformer whereas a lesser type of overcurrent will have a longer time lag to operate.

2. **Instantaneous overcurrent**:

Are mounted in the same case as the IDMT and is an overcurrent relay that operates instantaneously when a fault on the high voltage side is greater than the setting current.

3. **Balanced earth fault**:

An earth fault can only be one of the three phases. Under normal conditions the three voltages sum to zero, if there is an earth fault on one of the phases, then the difference in voltages will operate the relay.

4. **Buchholtz:**

When a fault occurs under the oil in a transformer, gas is generated and flows via a pipe into the oil conservancy tank on top of the transformer. Buchholtz is inserted on into the pipe and monitors the flow of gas. Severe faults will cause a lot of gas and the relay will operate immediately. For slow faults under the oil, the gradual built-up of gas in the tank will trigger the relay as soon as a certain concentration of gas is reached.

5. **Restricted earth fault**:

The phase connected current transformers (CT's) detect any earth fault but a balancing current is supplied by the neutral current transformer for an external fault. This restricts the operation of the relays within the transformer protection zone.

6. **Standby earth fault**:

This relay is normally the last line of defence and is intended to trip both the high voltage and low voltage sides of the transformer.

7. **Directional overcurrent:**

A phase fault between the transformer's low voltage circuit breaker and the transformer will cause both transformers to be tripped. Then to prevent this directional overcurrent relays are used on the secondary side and will only operate when fault current flows into the transformer.

Calculations of balanced loads

- **Ratio**

Transformation ratio of a three-phase transformer is the turns ratio or voltage ratio and is denoted by 'n'. It is the ratio of the primary turns to the secondary turns ratio can be expressed as $n = Np/Ns$. *It is utmost importance to remember to use phase values when using voltages*.

A 120kVA delta-star connected transformer is used to supply power to a clinic. It delivers 380V on each line. The transformer has a power factor of 0,9 lagging.

Determine the:

1. Secondary line current
2. Secondary phase current
3. Input power to the clinic

Given: S = 120 kVA

V_{LS} = 380V

p.f. = 0,9

solution:

1. $S = \sqrt{3} \times V_L I_L$

   $I_L = \frac{S}{\sqrt{3} \times V_L}$

   $= \frac{120000}{\sqrt{3} \times 380}$

   $= 182,32A$

2. $I_{PH} = I_L$

   $= 182,32A$

3. $P = \sqrt{3} \times V_L I_L cos Ø$

   $= \sqrt{3} \times 380 \times 182,32 \times 0,9$

   $= 108kW$