Electric Machines Laboratory (EE2P003)

EXPERIMENT-2

LEAKAGE IMPEDANCE OF A SINGLE PHASE THREE WINDING TRANSFORMER

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AIM OF THE EXPERIMENT:

To measure the leakage impedance of a single phase three winding transformer.

EQUIPMENTS REQUIRED:

Instruments/Equipment:

Sl.No	Instruments/Equipment	Type	Specification	Quantity
1.	Volt meter	MI	(0-75/150/300) V	1
2.	Ammeter	MI	(0-5)A	1
			(0-10)A	1
			(0-15)A	1
3.	Wattmeter	UPF	5/10A, 0-75/150/300V	1
4.	1-φ Autotransformer	Iron Core		1
5	Connecting wires	Cu	1.5 sq. mm	As required

Machines:

Sl. No.	Name of the machine	Specification
1.	Single Phase Three Winding Transformer	1.5kVA Primary:-415V, 3.6A Secondary:-230V,6.5A Tertiary:-110V,13.64A

THEORY:

Three-phase **three winding transformer** is modeled as **three** single- phase **three winding transformers**, meaning that only magnetic coupling between **windings** of the same phase are taken into account. The magnetization inductance Lm can be linear or with saturation, it is modeled on the primary side of the **transformer**

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The third winding is known as a tertiary winding which may be used for the following purposes:

- To supply a load at a voltage different from the secondary voltage.
- To provide a low impedance for the flow of certain abnormal currents, such a third harmonic currents.
- To provide for the excitation of a regulating transformer.

While both the primary and secondary winding of a two winding transformer have the same KVA rating, all the three windings of a three winding transformer may have different KVA ratings. The p.u. impedance in the impedance diagram should therefore be expressed on a common KVA basis.

When one winding is left open, the three winding transformer behaves as two winding transformer and standard short circuit tests can be used to evaluate per unit leakage impedances.

Zps = per unit leakage impedance measured from primary with secondary shorted and tertiary open.

Zpt = per unit leakage impedance measured from primary with tertiary shorted and secondary open.

Zst = per unit leakage impedance measured from secondary with tertiary shorted and primary open.

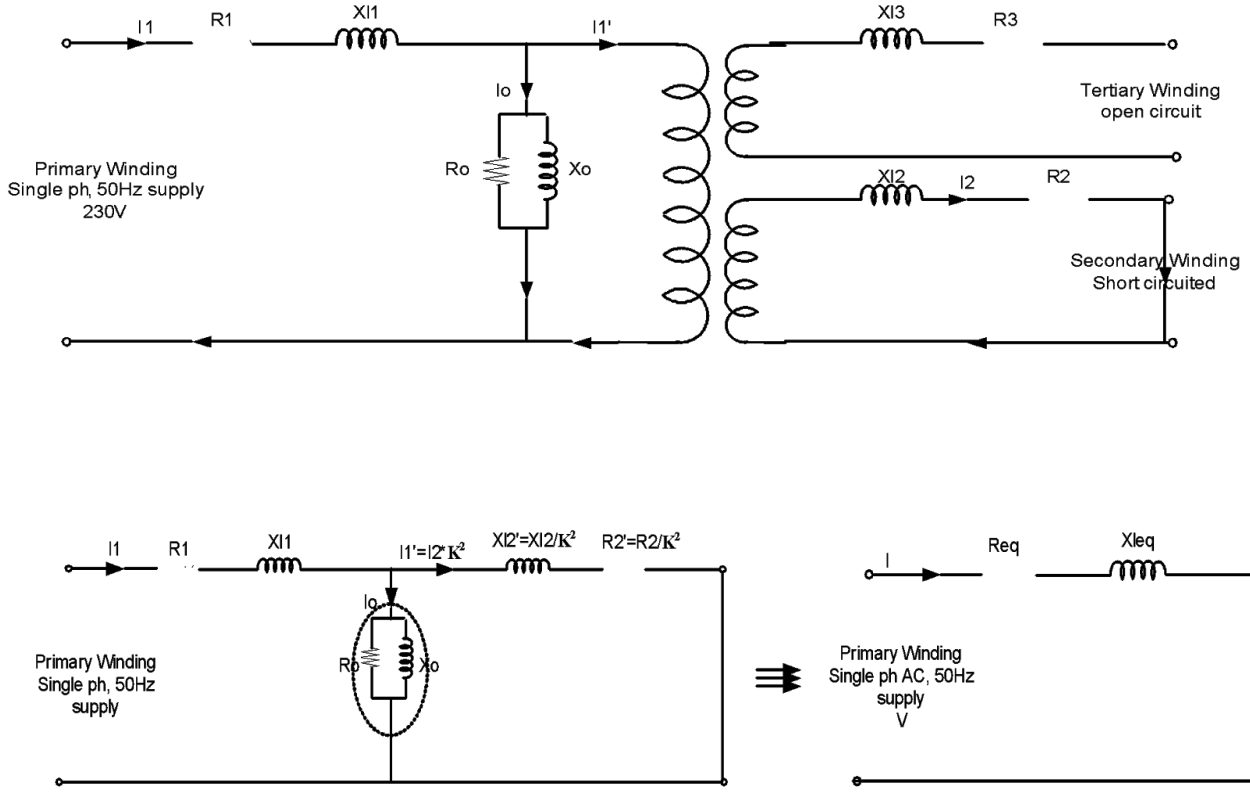
Let's consider the measurement of Zps, so the supply is given to primary, secondary is short circuited and tertiary is open. Now the three winding transformers behave as two winding transformers with primary and secondary. The equivalent circuit is like

R_1 =Resistance of primary winding, X_{l1} =Leakage reactance of primary winding

R_2 =Resistance of secondary winding, X_{l2} =Leakage reactance of secondary winding

R_1 =Resistance of tertiary winding, X_{l3} =Leakage reactance of tertiary winding

I_0= magnetizing current. (It is 0.02% of rated current. so it can be neglected when finding equivalent circuit)



Let Z_{ps}, Z_{pt}, and Z_{st} are leakage impedance of the primary, secondary and tertiary windings referred to as primary circuit. Then from transformer theory, we have -

$Zps = Zp + Zs/K^2$ ..... (a)

$Zpt = Zp + Zt/K^2$ ..... (b)

$Zst = Zs + Zt/K^2$..... (c)

Where Zp, Zs, and Zt : the impedances of primary, secondary and tertiary. $K=V_2/V_1$

Solving these equations, we find:

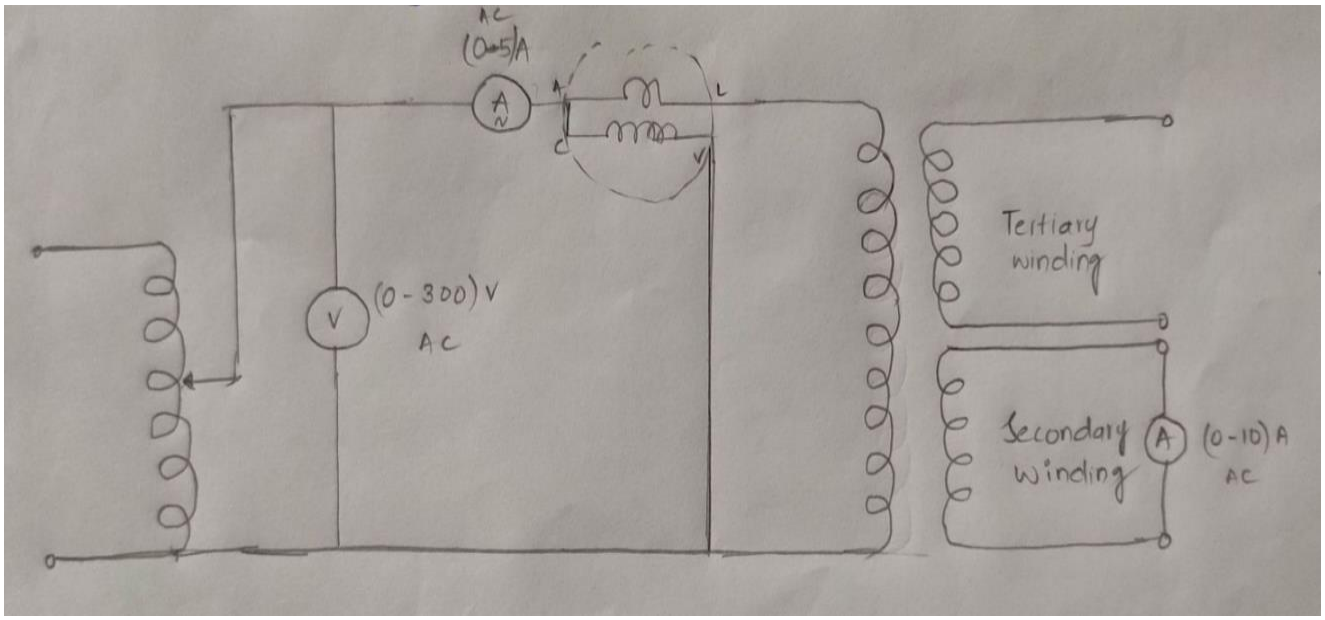
$Zp = ½ (Zps + Zpt - Zst)$ ..... (d)

$Zs = ½ (Zps + Zst - Zpt)$.....(e)

$Zt = ½ (Zpt + Zst – Zps)$…… (f)

These equations can be used to evaluate the per unit series impedances Zp, Zs, and Zt of three winding transformer equivalent circuits from the per unit impedances Zps, Zpt and Zst which in turn are determined from short circuit tests.

CIRCUIT DIAGRAM:



Circuit Diagram for measurement of leakage impedance (Zps)
Similarly circuit can be connected for Zpt and Zst.

OBSERVATIONS:

Table 1

SL. NO.	Winding	Rated voltage (Line to line KV)	Rated KVA (Three phase)
1.	Primary	415v	1.5
2.	Secondary	230v	1.5
3.	Tertiary	110v	1.5

Table 2

Sl. No.	Impedance to be measured	Impedance measured w.r.t winding	Winding short circuited	Winding open	Impedance(pu)
1	Z_{ps}	Primary	Secondary	tertiary	0.2166
2	Z_{pt}	Primary	tertiary	secondary	0.2039
3	Z_{st}	secondary	tertiary	primary	0.0381

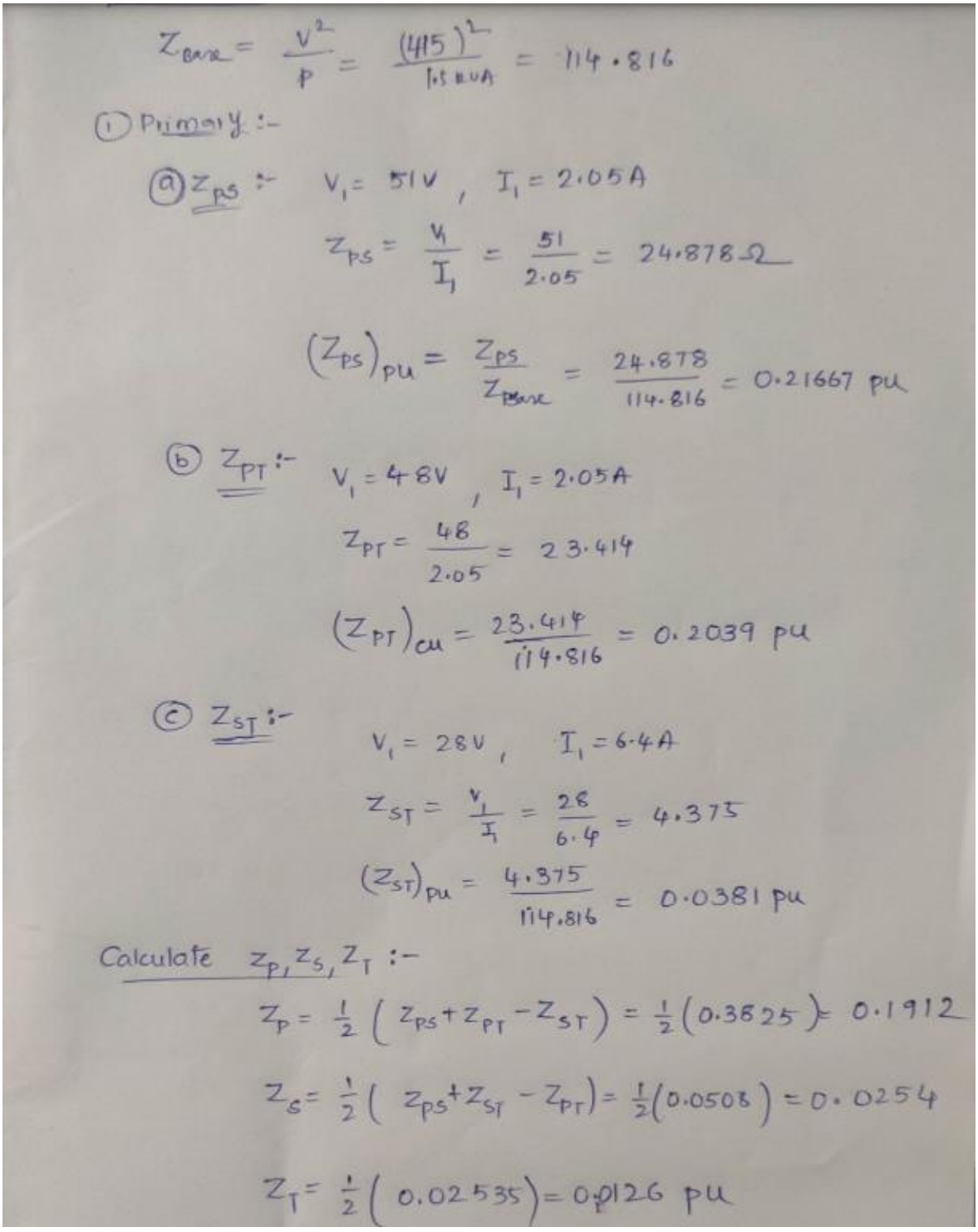
CALCULATIONS:

Z_{ps} = (Reading of voltmeter in primary side)/ (Reading of ammeter in primary side)

Z_{pt} = (Reading of voltmeter in primary side)/ (Reading of ammeter in primary side)

Z_{st} = (Reading of voltmeter in secondary side)/ (Reading of ammeter in secondary side)

Z_{st} measured is referred to secondary side so convert it to primary side.



Conclusion

We were successfully able to conduct the experiment and were able to measure the leakage impedance of a single phase three winding transformer

Hence in this way we find the leakage single phase three winding transformer. Here we got the leakage impedance of primary is greater than secondary and tertiary. The tertiary **winding** reduces the impedance of the circuit so that the fault current easily passes to the ground.

DISCUSSION

- **What is leakage reactance?**

In an ideal transformer, all the flux from primary winding will link to secondary. But in practical it is not possible to link all the flux. This flux which is not linked by both winding is called leakage flux. Due to this leakage flux in transformer, both primary and secondary windings have leakage reactance. There will be a voltage drop due these reactance's. Therefore, estimated efficiency is reduced.

- **What is the utility of a three phase three winding transformer?**

  - It is used in reducing the imbalance in voltages when the load is unbalanced.•3-winding transformer can be used for interconnecting transmission lines which are working at different voltage and power levels.
  - To regulate the voltage and reactive power of the system by providing synchronous capacitor connected to one of the terminals of the transformer
  - Providing tertiary winding helps to interconnect different power system operating at different voltages (Three winding transformer helps provide power supply at two different secondary voltages.)
  - The reactive power is supplied to the substations with the help of the tertiary **winding**.
  - The tertiary **winding** reduces the impedance of the circuit so that the fault current easily passes to the ground.
  - It is used for testing the high rating **transformer**.

- **What is the use of tertiary winding?**

  - The reactive power is supplied to the substations with the help of tertiary winding.
  - It is used for testing high rating transformers.
  - It reduces the impedance of the circuit so that fault current easily passes.
  - It redistributes the flow of fault current.
  - As tertiary winding is connected in delta formation in three winding transformers, it assists in the limitation of fault current in the event of a short circuit from line to neutral