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Power System Analysis

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Q1a:- You have Installed a photovoltic power system at your home. You want to export excess power produced by the system to the utility grid, what are the parameters that should be synchronized between the system (Generator) & Grid when connecting them?

Answer:- The power generated through photo-voltic system is used to operate the different types of Loads. Solar energy is harnessed by means of (PV) system which use arrays of PV panells that convert solar energy into electrical energy. It is cheap & more reliable as compared to other generating system. This system can be on small as well as to domestic use to fulfil the consumer demand for power. It is used as a backup source for purpose when the load on the power station increases For such purpose we synchronize our system to the grid to overcome lowe power problems. The inverter must convert the renewable energy stored in the battery bank into pure sinosidal voltage that tracks the grid voltage in amplitude, frequency & phase. For this purpose the inverter must be synchronized with the grid. The interconnection of photo-voltic (PV) system with grid requires an accurate control of synchronism between convert energy & Grid. The parameters including voltage, phase & frequency of both system need to be synchronized.

Q1 (b) Explain for each parameter what will happen if they are not synchronized.

Answer:- The following are the parameters through which we can synchronize a generator to the grid.

(1) Phase sequence.
(2) Voltage magnitude.
(3) Frequency.
(4) Phase Angle.

(1) Phase Sequence.

The phase sequence of the three phase of the generator must be the same as the phase sequence of the three phases of the grid. The generator or the transformer power leads could actually be interchanged during maintanance or the potential transformer leads could be interchanged during maintinance.

(2) Voltage Magnitude.

The magnitude of the sinusoidal voltage produced by the generator must be equal to the magnitude of the sinusoidal voltage of the grid. If all other conditions are met but the two voltages are not the same then there is a voltage differential closing of the AC generator. output breaker will cause a potentially large MVAR (Mega volts amps reactive) flow. If the generator voltage is higher then the grid this means that the internal voltage of the generator is higher then the grid voltage. when it is connected to the grid the generator will be overexcited & it will put out MVAR. If the generator voltage is less then the grid voltage, this means that the internal voltage of the generator is lower then the grid voltage. when it is connected to the grid the generator will be under-excited & will absorb MVAR

③ **Frequency.**

The frequency of the sinusoidal produced by the generator must be equal to the frequency of the sinusoidal voltage produced by the grid.

If the generator is slower then the grid then the synchroscope would be rotating rapidly counter clockwise. If the generator breaker were to be closed at that time the generator would be out of step with the external electrical system. It would behave like motor & the grid would try to bring it up to speed. In doing so the rotar & the starter would be slipping poles & damage the generator. The same problem would occur if the generator were faster then the grid.

④ **Phase Angle.**

The phase angle between the voltage produced by the generator & the voltage produced by the grid. The worst case occurs if the generator is exactly out of phase with the phase angle of 180°.

Q2(a):- Explain How we can determine if a 3-phase source & Load connected are a balanced system.

Answer:- A system is said to be balanced if the V_a, V_b & V_c of 3-phases sources are equal then the source is said to be balance & if the Z_a, Z_b & Z_c of 3-phase Load are equal then it is said to be balance.

Q2(b):- A 3-phase source has a voltage of $478\angle 45$ in +ve sequence. The system Frequency is 50 Hz. It is connected to a delta Load of $11\angle 40$. The system has a line impedence of 4ohm & 2 ohm. Find the Following.

1) Source Voltage.
2) Current.
3) Power.

Solution:- To Find the Total Load Impedence.

$Z_\Delta = R_s + Z_L$

$R_s = 4\Omega$.

$V_L = 478 \angle 45°$

$Z_L = 11 \angle 40°$

$R_u = 4\Omega$.

$Z_\Delta = 4\angle 0° + 11\angle 40°$

$Z_\Delta = (12.43 + j\,7.1)\,\Omega$

$Z_\Delta = 14.31 \angle 29.7\,\Omega$

The load is considered to be balanced.

Hence,

$V_L = V_{ph}$

$V_{AB} = 478 \angle 45° V$.

$V_{BC} = 478 \angle -75° V$

$V_{CA} = 478 \angle 165° V$

$$I_a = \frac{478 \angle 45° - 30°}{\sqrt{3} \times 14.31 \angle 29.7°}$$

$I_a = (19.28 \angle -14.7)$ A.

$I_b = 19.28 \angle -14.7 - 120°$

$I_b = (19.28 \angle -134.7°)$ A

$I_c = 19.28 \angle -14.7 + 120°$

$I_C = (19.28\angle 105.3^\circ)$ A

Hence power factor is not given so we will prefer to find only apparent power.

$$S = \sqrt{3}\, V_L\, I_L$$

Since $I_L = (0.31\angle 101.3^\circ)$ A

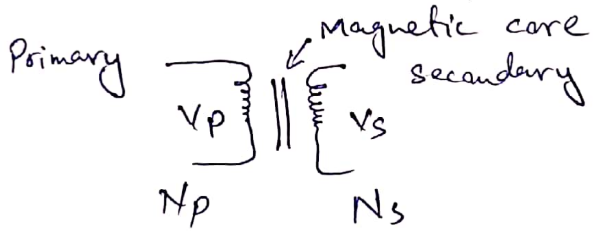
So

$$S = \sqrt{3} * 478\angle 45^\circ * 0.31\angle 101.3^\circ$$

$$S = (256.65\angle -56.3)\ VA.$$

Q3 (a) Explain & Draw the complete circuit diagram of single phase ~~tr~~ transformer.

Answer:-



where

V_p = Primary Voltage
V_s = Secondary voltage.
N_p = No of primary winding
N_s = No of secondary winding.

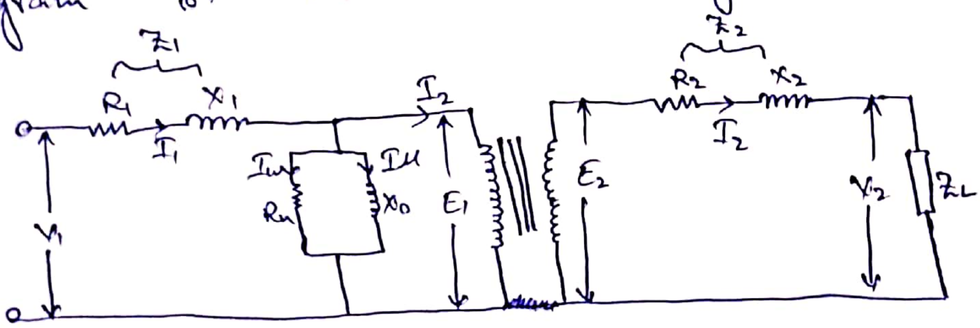
In transformer the two coil windings are not physically linked but only linked magnetically.

It can flow current from ~~one~~ primary winding to the secondary winding keeping the frequency constant. The transformer ~~are~~ ~~is~~ may be step-up or step-down depending ~~upon~~ upon the winding of the transformer.

Then convert it into the equivalent circuit diagram of an ideal transformer step wise with explaination.

Equivalent circuit diagram of single phase Transformer.

Equivalent circuit diagram of a transformer is basically a diagram which can be resolved into an equivalent circuit ~~diagram~~ in which the resistance & leakage resistance of the transformer are imaginated to be external to the winding the equivalent ckt diagram of transformer is given below.



where :-

R_1 = Primary winding Resistance.

R_2 = Secondary winding Resistance.

I_0 = No-Load current.

I_M = Magnetizing component.

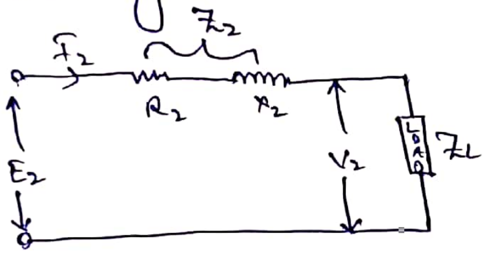
I_w = Working component.

This I_M & I_w are connected in parallel across the primary circuit. The value of E_1

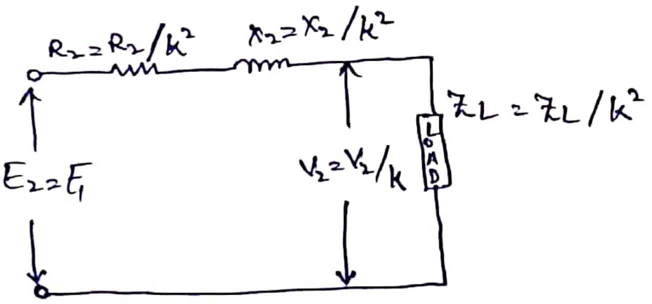
(Primary EMF) is obtained by subtracting vectorially $I_1 Z_1$ from V_1. The value of Z_0 $X_0 = E_1/I_0$ & $R_0 = E_1/I_w$. We know that the relation of E_1 & E_2 is $E_2/E_1 = N_2/N_1 = K$

From the equivalent circuit we can easily calculate the total impedence of to transfer voltage, current & impedence either to the primary or to the secondary.

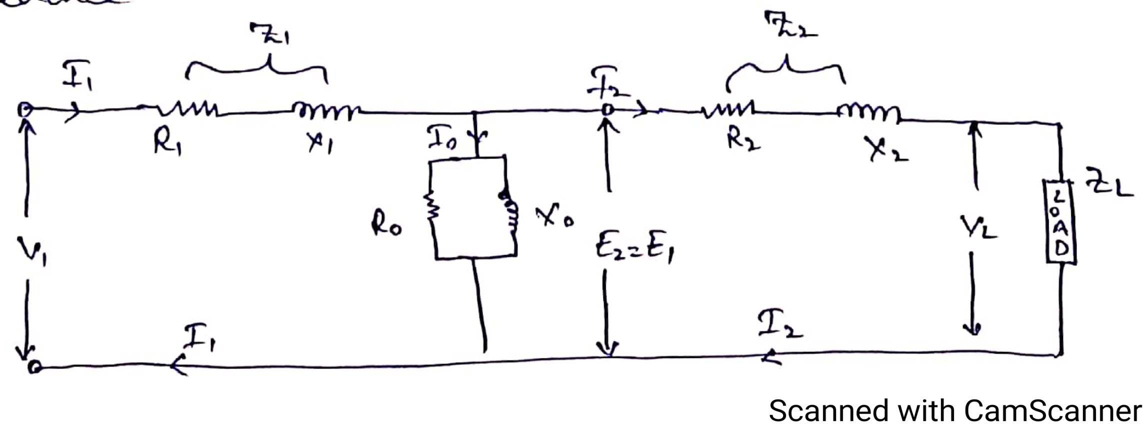
The secondary circuit is



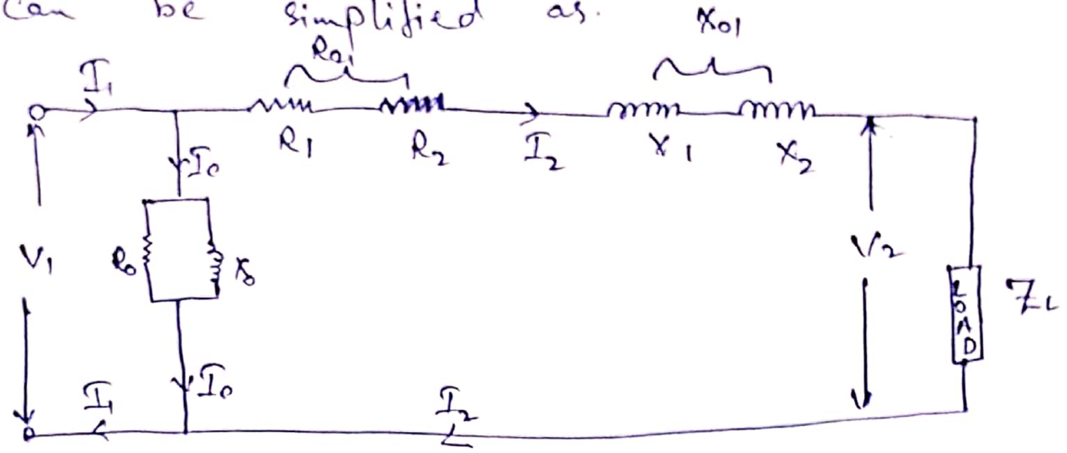
& its Equivalent primary value is



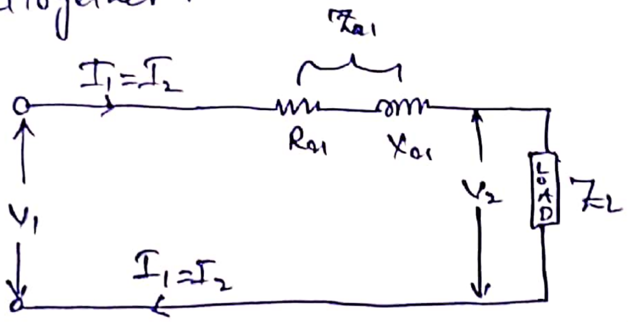
The total equivalent circuit of the transformer is obtained by adding in the primary impedence.



It can be simplified as.



Further it can be simplified by omitting I_0 altogether.



So the total input between the input terminals is

$$Z = Z_1 + Z_m \parallel (Z_2 + Z_L) = \left(Z_1 + \frac{Z_m(Z_m + Z_L)}{Z_m + (Z_2 + Z_L)} \right)$$

This is ~~balance~~ ~~hence~~ because there are two parallel circuits, one having impedence of Z_m & the other having Z_2 & Z_L in series with each other.

So

$$V_1 = I_1 \left[Z_1 + \frac{Z_m(Z_m + Z_L)}{Z_m + (Z_2 + Z_L)} \right].$$

Q3(b) :- A single phase two winding transformer is rated 20kVA, 480/120 volts, 50Hz. During a short-circuit, where rated current at rated frequency is applied to the winding 1, with winding 2 shorted. The following readings are obtained. VI = 78v, PI = 114 W. Determine the equivalent series impedence $Z_{eq}I = R_{eq}I + j X_{eq}I$. reffered to winding 1. Neglect the shunt addmittance.

Solution:- The equivalent circuit for the short-circuit test is where the shunt addmitance branch is neglected. Rated current for winding 1 is.

$$I_1 \text{ rated} = \frac{S \text{ rated}}{V_1 \text{ rated}} = \frac{20 \times 10^3}{480} = 41.667 A$$

$R_{eq}1$, $Z_{eq}1$ & $X_{eq}1$ are then Determined as follows.

$$R_{eq}1 = \frac{P_1}{I_1^2 \text{ rated}} = \frac{114}{(41.667)^2} = 0.0656\,\Omega$$

$$|Z_{eq}1| = \frac{V_1}{I_1 \text{ rated}} = \frac{11v}{41.667} = 0.2639\,\Omega$$

$$X_{eq}1 = \sqrt{Z_{eq}1^2 - R_{eq}1^2} = 0.2555\,\Omega$$

$$Z_{eq}1 = R_{eq1} + j X_{eq}1 = 0.0656 + j\,0.2555\,\Omega$$