MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

LECTURE HANDOUTS

L 1

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Current and Voltage Laws, Node and Mesh Analysis

Introduction : Circuit theory is a linear analysis; i.e., the voltage-current relationships for R, L, and C are linear relationships, as R, L, and C are considered to be constants over a large range of voltage and currents. The response due to all sources present in the circuit is then the sum of the individual responses.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **voltage**
2. **current**
3. **active and passive component**

Detailed content of the Lecture:

Kirchhoff's Voltage Law

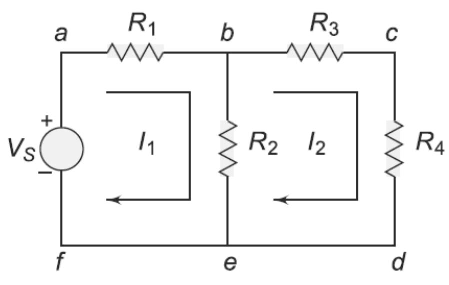
Kirchhoff 's voltage law states that the algebraic sum of all branch voltages around any closed path in a circuit is always zero at all instants of time..

Kirchhoff's Current Law

Kirchhoff 's current law states that the sum of the currents entering into any node is equal to the sum of the currents leaving that node.

Mesh Analysis

Mesh analysis is applicable only for planar networks. For non-planar circuits, mesh analysis is not applicable. A circuit is said to be planar if it can be drawn on a plane surface without crossovers. A non-planar circuit cannot be drawn on a plane surface without a crossover.



Observation of Fig. indicates that there are two loops abefa, and bcdeb in the network. Let us assume loop currents I1 and I2 with directions as indicated in the figure. Considering the loop abefa alone, we observe that current I1 is passing through R1, and (I1 – I2) is passing through R2.

By applying Kirchhoff's voltage law, we can write Vs = I1R1 1 R2(I1 – I2) Similarly, if we consider the second mesh bcdeb, the current I2 is passing through R3 and R4, and (I2 – I1) is passing through R2. By applying Kirchhoff's voltage law around the second mesh, we have R2 (I2 – I1) + R3 I2 + R4 I2 = 0

By rearranging the above equations, the corresponding mesh current equations are

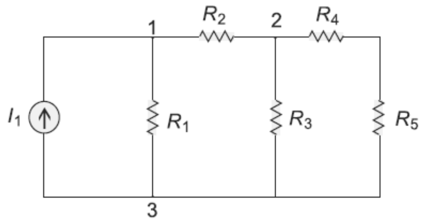
$$I1(R1 + R2) - I2\,R2 = Vs$$

$$-I1\,R2 + (R2 + R3 + R4)I2 = 0$$

By solving the above equations, we can find the currents I1 and I2. If we observe, the circuit consists of five branches and four nodes, including the reference node. The number of mesh currents is equal to the number of mesh equations.

Nodal Analysis:

Each node in a circuit can be assigned a number or a letter. The node voltage is the voltage of a given node with respect to one particular node, called the reference node, which we assume at zero potential. In the circuit shown in Fig, the node 3 is assumed as the reference node. The voltage at the node 1 is the voltage at that node with respect to the node 3. Similarly, the voltage at the node 2 is the voltage at that node with respect to the node 3. Applying Kirchhoff's current law at the node 1; the current entering is equal to the current leaving



$$I_1 = \frac{V_1}{R_1} + \frac{V_1 - V_2}{R_2}$$

Here, V1 and V2 are the voltages at nodes 1 and 2, respectively. Similarly, at the node 2, the current entering is equal to the current leaving as shown in Fig.

$$\frac{V_2 - V_1}{R_2} + \frac{V_2}{R_3} + \frac{V_2}{R_4 + R_5} = 0$$

Rearranging the above equations, we have

$$V_1\left[\frac{1}{R_1} + \frac{1}{R_2}\right] - V_2\left[\frac{1}{R_2}\right] = I_1$$

$$-V_1\left[\frac{1}{R_2}\right] + V_2\left[\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4 + R_5}\right] = 0$$

Video Content / Details of website for further learning (if any):

https://youtu.be/dlROTnDbULo

https://youtu.be/fHj2RdOnTqg

https://youtu.be/SkBAJ7TooDk

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:14 to 17,68 to 81

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LECTURE HANDOUTS

L 2

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Theorems: Superposition, Thevenin and Norton,

Introduction : Network Theory is the study of how to solve circuit problems. By analyzing circuits, to determine the various voltages can currents with exist within the network. When looking at solving any circuit, a number of methods and theories exist to assist and simplify the process. They mainly help in simplification of a complex circuit and easily let us calculate the current/voltage through a component of interest. Thévenin's theorem and its dual, Norton's theorem , are widely used to make circuit analysis simpler and to study a circuit's initial-condition and steady-state response.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **sources**
2. **voltage**
3. **current**

Detailed content of the Lecture:

Superposition Theorem

The superposition theorem states that in any linear network containing two or more sources, the response in any element is equal to the algebraic sum of the responses caused by individual sources acting alone, while the other sources are non-operative; that is, while considering the effect of individual sources, other ideal voltage sources and ideal current sources in the network are replaced by short circuit and open circuit across their terminals. This theorem is valid only for linear systems.

Thevenin's Theorem

In many practical applications, it is always not necessary to analyse the complete circuit; it requires that the voltage, current, or power in only one resistance of a circuit be found. The use of this theorem provides a simple, equivalent circuit which can be substituted for the original network. Thevenin's theorem states that any two terminal linear network having a number of voltage current sources and resistances can be replaced by a simple equivalent circuit consisting of a single voltage source in series with a resistance, where the value of the voltage source is equal to the open-circuit voltage across the two terminals of the network, and resistance is equal to the equivalent resistance measured between the terminals with all the energy sources are replaced by their internal resistances. Procedure to apply this theorem.

Step 1: Define which part of circuit must get Thévenin equivalent. This part must have two terminals.

Step 2: Remove any component between these terminals which are not part of circuit to obtain Thévenin equivalent.

Step 3: Find Thévenin's equivalent resistance, transform all voltage sources in short-circuit and current sources in open circuit.

Step 4: Restore sources in original positions. Calculate voltages between terminals of equivalent circuit and make step 2 again. This is Thévenin voltage.

Norton's Theorem

Another method of analysing the circuit is given by Norton's theorem, which states that any two terminal linear network with current sources, voltage sources and resistances can be replaced by an equivalent circuit consisting of a current source in parallel with a resistance. The value of the current source is the short-circuit current between the two terminals of the network and the resistance is the equivalent resistance measured between the terminals of the network with all the energy sources are replaced by their internal resistance.

$$IN = VTh/R$$

Where IN is Norton current and R is equivalent resistance equal to both Thévenin and Norton.

Procedure to apply this theorem.

Step 1: Define which part of circuit must get Thévenin equivalent. This part must have two terminals.

Step 2: Remove any component between these terminals which are not part of circuit to obtain Thévenin equivalent.

Step 3: Find Thévenin's equivalent resistance, transform all voltage sources in short-circuit and current sources in open circuit.

step 4: must calculate Norton current In, which is a short-circuit current in terminals of circuit.

Video Content / Details of website for further learning (if any):

https://youtu.be/veAFVTIpKyM
https://youtu.be/RkSN_JxBGt0
https://youtu.be/ZJ8zD8m-B1Q

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:115 to 125

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LECTURE HANDOUTS

L3

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Maximum power transfer,Reciprocity, Tellegens

Introduction : Solving for currents and voltages in multi-loop electric circuits can be quite complicated, particulary for AC circuits. The voltage law and current law always apply, but using them may lead to long systems of equations. Certain theorems help with network analysis.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **ohm's law**
2. **voltage law**
3. **current law**

Detailed content of the Lecture:

Maximum Power Transfer Theorem

This theorem explains the condition for the maximum power transfer to load under various circuit conditions. The theorem states that the power transfer by a source to a load is maximum in a network when the load resistance is equal to the internal resistance of the source. For AC circuits load impedance should match with the source impedance for maximum power transfer even if the load is operating at different power factors.

Where in a circuit is simplified up to a level of source with internal resistance using Thevenin's theorem. The power transfer will be maximum when this Thevinens resistance is equal to the load resistance. The Practical application of this theorem includes an audio system wherein the resistance of the speaker must be matched to the audio power amplifier to obtain maximum output.

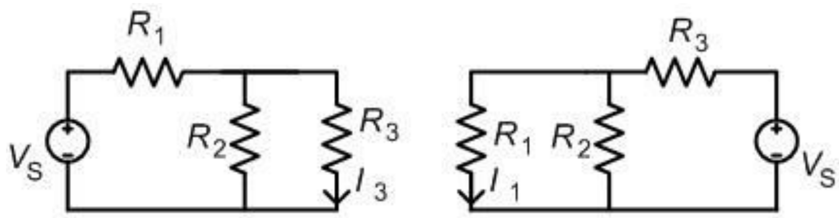
This theorem states that in an active, linear, bilateral network, maximum power is delivered to the load when the load resistance is equal to the equivalent resistance looking back into the network from the terminals where the load is connected.

The value of the maximum power is given by V^2Consider a network with a source of emf E and internal resistance r connected to a load resistance $R_L$he power delivered to the load resistance is maximum when the load resistance is equal to the internal resistance of the source. The power versus resistance curve is parabolic in nature.

And the maximum power delivered to the load is only half the power generated by the source or the maximum power transfer efficiency is 50%. The remaining 50% power is lost across the internal resistance of the source.

Reciprocity Theorem

Reciprocity theorem helps to find the other corresponding solution even without further work, once the circuit is analyzed for one solution. The theorem states that in a linear passive bilateral network, the excitation source and its corresponding response can be interchanged.



In the above figure, the current in the R3 branch is I3 with a single source Vs. If this source is replaced to the R3 branch and shorting the source at the original location, then the current flowing from the original location I1is the same as that of I3. This is how we can find corresponding solutions for the circuit once the circuit is analyzed with one solution.

Tellegen's theorem

$$\sum_{k=1}^{n} P_k = V_k \times I_k = 0$$

This theorem is applicable for circuits with a linear or nonlinear, passive, or active and hysteric or non-hysteric networks. It states that the summation of instantaneous power in the circuit with n number of branches is zero.

Video Content / Details of website for further learning (if any):

https://youtu.be/U85eA3-suiQ
https://youtu.be/FIgSHt2GXxU
https://youtu.be/bIzyKFKkaV4

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:127 to 132

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LECTURE HANDOUTS

L 4

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Compensation and Milliman's theorem

Introduction :

The theorem states that the power transfer by a source to a load is maximum in a network when the load resistance is equal to the internal resistance of the source.The power transfer will be maximum when this Thevinens resistance is equal to the load resistance.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Inductor**
2. **Force**
3. **Conductor**
4. **Magnetic field**

Detailed content of the Lecture:

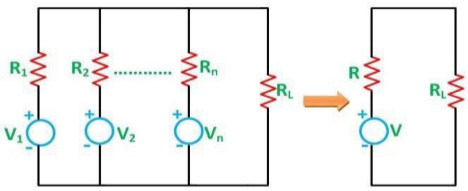
Compensation Theorem:

This theorem is based on one basic concept. According to Ohm's law, when current flows through any resistor, there would be a voltage drop across the resistor. This dropped voltage opposes the source voltage. Hence voltage drop across a resistance in any network can be assumed as a voltage source acting opposite to the source voltage. The **compensation theorem** depends upon this concept.

This imaginary voltage source is directed opposite to the voltage source of that replaced resistance. Think about a resistive branch of any complex network that's value is R. Let's assume current I is flowing through that resistor R and voltage drops due to this current across the resistor is V = I.R. According to **compensation theorem**, this resistor can be replaced by a voltage source that's generated voltage will be V (= IR) and will be directed against the direction of network voltage or direction of current I.

Millman's theorem:

The utility of **Millman's Theorem** is that the number of parallel voltage sources can be reduced to one equivalent source. It is applicable only to solve the parallel branch with one resistance connected to one voltage source or current source. It is also used in solving network having an unbalanced bridge circuit.



As per Millman's Theorem

$$V = \frac{\pm V_1G_1 \pm V_2G_2 \pm \dots\dots\dots \pm V_nG_n}{G_1 + G_2 + \dots\dots . + G_n} \quad \text{and}$$

$$R = \frac{1}{G} = \frac{1}{G_1 + G_2 + ,,,,,,, + G_n}$$

Steps for Solving Millman's Theorem

Step 1 – Obtain the conductance (G_1, G_2,….) of each voltage source (V_1, V_2,….).

Step 2 – Find the value of equivalent conductance G by removing the load from the network.

Step 3 – Now, apply Millman's Theorem to find the equivalent voltage source V by the equation shown below

$$V = \frac{\pm V_1G_1 \pm V_2G_2 \pm \dots\dots\dots \pm V_nG_n}{G_1 + G_2 + \dots\dots . + G_n}$$

Step 4 – Determine the equivalent series resistance (R) with the equivalent voltage sources (V) by the equation

$$R = \frac{1}{G}$$

Step 5 – Find the current I_L flowing in the circuit across the load resistance R_L by the equation

$$I_L = \frac{V}{R + R_L}$$

Video Content / Details of website for further learning (if any):

https://youtu.be/5ljdVbQTsrE
https://youtu.be/ynNRjKgcE2A

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:131 to 138.

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LECTURE HANDOUTS

L 5

ECE

II/ III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Source free circuit, Properties of Exponential Response and Step function functions

Introduction : Source-Free Circuits. A source-free circuit is one where all independent sources have been disconnected from the circuit after some switch action. The voltages and currents in the circuit typically will have some transient response due to initial conditions (initial capacitor voltages and initial inductor currents).

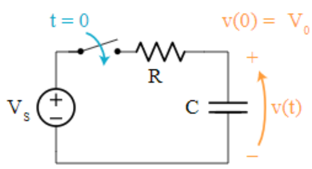
Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Capacitor**
2. **Frequency**
3. **Reactance**

Detailed content of the Lecture:

RC step response

Let's cause an abrupt step in voltage to a resistor-capacitor (RC) circuit and observe what happens to the voltage across the capacitor.



We want to find the voltage v(t) across the capacitor as a function of time.When something changes in a circuit, like a switch closes, the voltages and currents in the circuit elements adjust to the new conditions. If the change is an abrupt step, as it is here, the response of the voltages and currents is called the step response. The step response is a common way to give a circuit to see what it does. It tells us quite a lot about the properties of the circuit.

The total response of a circuit can be teased apart into a *forced response* plus a *natural response*. These responses can be combined using the principle of superposition.

The forced response is calculated with the sources turned on, but with the initial conditions (internal stored energy) set to zero.

The natural response is what the circuit does including the initial conditions, (initial voltage on capacitors or current in inductors), but with input suppressed.

total = forced + natural

We derive the step response network using this method of forced and natural response:

$v(t)$=VS+ (V0−VS)e−t/RC

VS is the height of the voltage step.

V0 is the initial voltage on the capacitor.

Find the RC step response

We are interested in the voltage on the capacitor, vvv as a function of time. We start by looking at what happens before the switch closes. Then we jump way out in time to a long time from now, and figure out where the circuit finishes up. Finally, we look at what happens in between the switch closing and a long time from now.

Initial state

Before the switch is closed, (t<0) the schematic tells us an initial voltage exists on the capacitor: v(0) = 0, We know the current in the circuit is 0 because the switch is open. These are the initial conditions of the circuit

Final state

If we close the switch at t=0t=0t, equals, 0, current will start flowing around the now-completed circuit. Current will continue to flow as long as there is a voltage difference across the resistor.At some point in the future, the capacitor voltage, v, will become the same as the source voltageVS. When this happens, the voltage across the resistor, VS will be 0, and current will fall to0. This is the *final state* of the circuit.

Transient period

Between the initial state and the final state the current and voltage adjust to new conditions imposed by the voltage source. This is called the transient period, when things are changing. The change v makes during this time is the transient response of the RC. In our example, the switch closing event applies a voltage step to the , R, C, end text circuit, so this is also called the *step* response.

Video Content / Details of website for further learning (if any):

https://youtu.be/NsP4XoIJec0
https://youtu.be/TOlmxh5ouao

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:466

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LECTURE HANDOUTS

L 6

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Natural and Forced Response

Introduction: The forced response is what the circuit does with the sources turned on, but with the initial conditions set to zero. The natural response is what the circuit does including the initial conditions, but with the input suppressed. The total response is the sum of the forced response plus the natural response.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Forced response**
2. **Signal**
3. **Natural response**

Detailed content of the Lecture:

The forced and natural response

The two complications (input signal and initial conditions) make solving a non-homogeneous equation somewhat of a chore, the math can be tricky. Our strategy, as usual, is to break the problem into parts. We separate the larger problem into two simpler problems by teasing apart the forced and natural response. Solving the forced and natural responses separately is simpler than going head-on at the non-homogeneous equation.

The forced response is where the output (the voltage on the capacitor) is going to end up in the long run after all stored energy eventually dissipates. The forced response does this by ignoring the presence of energy storage elements (in this case, it ignores the capacitor and its initial voltage).

The forced response can't tell us what happens at the beginning when the switch closes, or during the transition to the final state, because it ignores the stored energy. For that, we need the natural response.

The natural response tells us what the circuit does as its internal stored energy (the initial voltage on the capacitor) is allowed to dissipate. It does this by ignoring the forcing input (the voltage step caused by the switch closing). The "destination" of the natural response is always zero voltage and zero current.

In the end, we combine the forced and natural responses to get the full story. The forced response impresses its will on the natural response and gives it a destination different from zero. This gives us the total response.

The application of KVL and KCL to circuits containing energy storage elements results in differential, rather than algebraic, equations. When we consider a circuit containing storage elements which are independent of the sources, the response depends upon the nature of the circuit and is called the natural response. Storage elements deliver their energy to the resistances. Hence, the response changes with time, gets saturated after some time, and is referred to as the transient response.

When we consider sources acting on a circuit, the response depends on the nature of the source or sources. This response is called forced response. In other words, the complete response of a circuit consists of two parts: the forced response and the transient response. When we consider a differential equation, the complete solution consists of two parts: the complementary function and the particular solution.

Video Content / Details of website for further learning (if any):

https://youtu.be/xKNv2gXYzlk

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:466 to 467.

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LECTURE HANDOUTS

L 7

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Driven RL and RC circuits

Introduction : In a network containing energy storage elements, with change in excitation, the currents and voltages change from one state to another state. The behavior of the voltage or current when it is changed from one state to another is called the transient state. The time taken for the circuit to change from one steady state to another steady state is called the transient time.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Resistor**
2. **kirchhoff's voltage law**
3. **kirchhoff's current law**

Detailed content of the Lecture:

The method for solving a circuit driven by an external source is:

Set the initial conditions to 0 and solve the forced response.

Set the input to 0, and solve the natural response.

Add the forced response to the natural response to get the total response.

Use the initial conditions to resolve any constants.

Dc Response Of An R-L Circuit

Consider a circuit consisting of a resistance and inductance as shown in Fig. The inductor in the circuit is initially uncharged and is in series with the resistor. When the switch S is closed, we can find the complete solution for the current. Application of Kirchhoff 's voltage law to the circuit results in the following differential equation.

$V = Ri + L\, di/dt$

$di/dt + R\, i/L = V/L$

In the above equation, the current i is the solution to be found and V is the applied constant voltage. The voltage V is applied to the circuit only when the switch S is closed. The above equation is a linear differential equation of first order. Comparing it with a non-homogeneous differential equation

$dx/dt + Px = K$

whose solution is

$$x = e^{-pt} \int K e^{+Pt} dt + c e^{-Pt}$$

where c is an arbitrary constant. In a similar way, we can write the current equation as

$$i = c e^{-(R/L)t} + e^{-(R/L)t} \int \frac{V}{L} e^{(R/L)t} dt$$

$$\therefore \quad i = c e^{-(R/L)t} + \frac{V}{R}$$

the transient part of the solution is

$$i = -\frac{V}{R} \exp\left(-\frac{R}{L} t\right) = \frac{V}{R} e^{-t/\tau}$$

Dc Response Of An R-C Circuit

Consider a circuit consisting of resistance and capacitance .The capacitor in the circuit is initially uncharged, and is in series with a resistor. When the switch S is closed at t = 0, we can determine the complete solution for the current. Application of the Kirchhoff's voltage law to the circuit results in the following differential equation.

$$V = Ri + \frac{1}{C} \int i \, dt$$

the current equation becomes

$$i = \frac{V}{R} e^{-t/RC}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=AUeCB5Iy5fA
https://www.youtube.com/watch?v=saVHfHO_CFU

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:467 to 469.

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LECTURE HANDOUTS | **L 8**

ECE | **II / III**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS** **Date of Lecture:**

Topic of Lecture: Source free, damped and underdamped parallel RLC circuit, Critical Damping

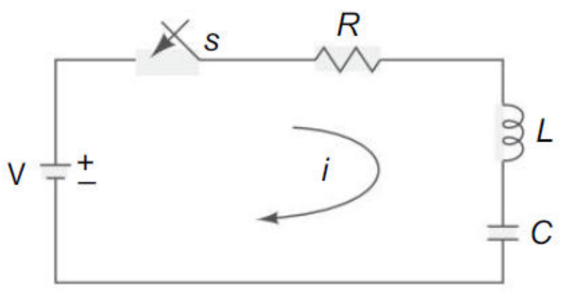
Introduction : The resonant frequency for an RLC circuit is the same as a circuit in which there is no damping, hence undamped resonance frequency. A circuit with a value of resistor that causes it to be just on the edge of ringing is called critically damped.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Resistor**
2. **Capacitor**
3. **kirchhoff's law**

Detailed content of the Lecture:

Consider a circuit consisting of resistance, inductance, and capacitance as shown in Fig. The capacitor and inductor are initially uncharged, and are in series with a resistor. When the switch S is closed at t =0, we can determine the complete solution for the current. Application of Kirchhoff's voltage law to the circuit results in the following differential equation.



$$V = Ri + L\frac{di}{dt} + \frac{1}{C}\int i\,dt$$

Second-order linear differential equation, with only complementary function. The particular solution for the above equation is zero. Characteristic equation for the above differential equation is

$$\left(D^2 + \frac{R}{L}D + \frac{1}{LC}\right) = 0$$

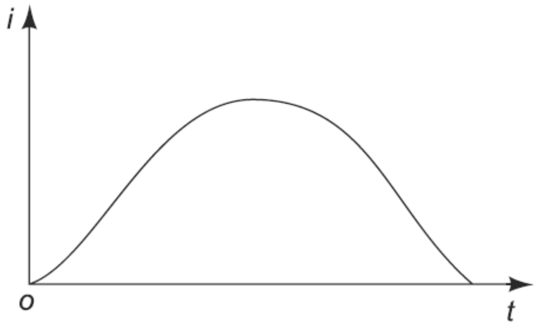
$$D_1, D_2 = -\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

By assuming $K_1 = -\frac{R}{2L}$ and $K_2 = \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$

$$D_1 = K_1 + K_2 \text{ and } D_2 = K_1 - K_2$$

Here, K_2 may be positive, negative or zero.

K_2 is positive, when $\left(\frac{R}{2L}\right)^2 > 1/LC$



The roots are real and unequal, and give the over damped response becomes

[D – (K1+ K2)] [D – (K1 – K2)] i =0

The solution for the above equation is

i = c1e(K1 +K2)t +c2 e(K1 – K2)t

The current curve for the over damped case

K2 is negative, when (R/2L)2 < 1/LC

The roots are complex conjugate, and give the under damped response

[D – (K1 +jK2)] [D – (K1 – jK2)]i =0

The solution for the above equation is

i =eK1t [c1 cos K2t+ c2 sin K2t]

K2 is zero, when (R/2L)2 =1/LC

The roots are equal, and give the critically damped response

(D – K1) (D – K1)i =0

The solution for the above equation is

i = eK1t(c1 +c2t)

Video Content / Details of website for further learning (if any):

https://youtu.be/IST5IV-fPtQ
https://youtu.be/If25y4Nhvw4

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:468.

Course Faculty

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LECTURE HANDOUTS

L 9

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **I – THEOREMS AND DC TRANSIENT ANALYSIS**

Date of Lecture:

Topic of Lecture: Source free series RLC, Complete Response and lossless Circuits

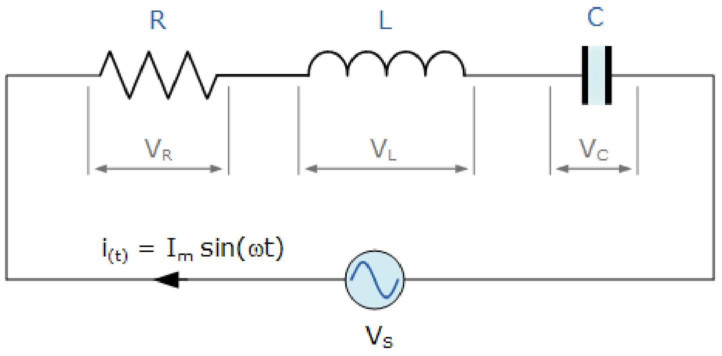
Introduction : The resonance of a series RLC circuit occurs when the inductive and capacitive reactance are equal in magnitude but cancel each other because they are 180 degrees apart in phase. The sharp minimum in impedance which occurs is useful in tuning applications.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **voltage**
2. **current**
3. **power**

Detailed content of the Lecture:

Series RLC circuits consist of a resistance, a capacitance and an inductance connected in series across an alternating supply The analysis of a **series RLC circuit** is the same as that for the dual series R_L and R_C circuits we looked at previously, except this time we need to take into account the magnitudes of both X_L and X_C to find the overall circuit reactance. Series RLC circuits are classed as second-order circuits because they contain two energy storage elements, an inductance L and a capacitance C.



The series RLC circuit above has a single loop with the instantaneous current flowing through the loop being the same for each circuit element. Since the inductive and capacitive reactance's X_L and X_C are a function of the supply frequency, the sinusoidal response of a series RLC circuit will therefore vary with frequency, *ƒ*. Then the individual voltage drops across each circuit element of R, L and C element will be "out-of-phase" with each other as defined by:

$i_{(t)} = I_{max} \sin(\omega t)$

The instantaneous voltage across a pure resistor, V_R is "in-phase" with current

The instantaneous voltage across a pure inductor, V_L "leads" the current by 90^o

The instantaneous voltage across a pure capacitor, V_C "lags" the current by 90^o

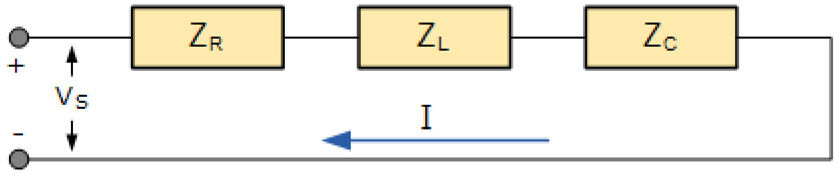
Therefore, V_L and V_C are 180^o "out-of-phase" and in opposition to each other.

the amplitude of the source voltage across all three components in a series RLC circuit is made up of the three individual component voltages, V_R, V_L and V_C with the current common to all three components. The vector diagrams will therefore have the current vector as their reference with the three voltage vectors being plotted with respect to this reference

In a **series RLC circuit** containing a resistor, an inductor and a capacitor the source voltage V_S is the phasor sum made up of three components, V_R, V_L and V_C with the current common to all three. Since the current is common to all three components it is used as the horizontal reference when constructing a voltage triangle.

The impedance of the circuit is the total opposition to the flow of current. For a series RLC circuit, and impedance triangle can be drawn by dividing each side of the voltage triangle by its current, I. The voltage drop across the resistive element is equal to I*R, the voltage across the two reactive elements is $I*X = I*X_L - I*X_C$ while the source voltage is equal to I*Z. The angle between V_S and I will be the phase angle, θ.

When working with a series RLC circuit containing multiple resistances, capacitance's or inductance's either pure or impure, they can be all added together to form a single component. For example all resistances are added together, $R_T = (R_1 + R_2 + R_3)$...etc or all the inductance's $L_T = (L_1 + L_2 + L_3)$...etc this way a circuit containing many elements can be easily reduced to a single impedance.



$$Z_T = \frac{V_S}{I} = Z_R + Z_L + Z_C$$

Video Content / Details of website for further learning (if any):

https://youtu.be/If25y4Nhvw4

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:468.

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LECTURE HANDOUTS | **L 10**

ECE | **II / III**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS** **Date of Lecture:**

Topic of Lecture: Characteristic of Steady State Analysis

Introduction : A steady state flow process requires conditions at all points in an apparatus remain constant as time changes. There must be no accumulation of mass or energy over the time period of interest. The same mass flow rate will remain constant in the flow path through each element of the system.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Sinusoidal signal**
2. **voltage**
3. **current**
4. **frequency**

Detailed content of the Lecture:

Almost all electrical systems, whether signal or power, operate with alternating currents and voltages. We have seen that when any circuit is disturbed (switched on or off etc.) it undergoes a transient period when voltages and currents can vary wildly and are characterized by their values being enclosed within decaying exponential envelopes. After the transient comes the steady-state period; and the term "Sinusoidal Steady-State" refers to how ac circuits are modeled once the transient has passed.

It may seem that we are being overly restrictive to confine ourselves to ac waveforms, but we know that any periodic waveform can be represented by a series of sinusoidal waveforms, so studying a single sinusoidal waveform at this stage will make subsequent analysis easier.

It is important for all engineers to be able to analyze steady-state conditions, because it is the steady-state that determines continuous ratings of the equipment.

Failure to correctly size equipment results in either:

- excessive expenditure of capital when the plant is oversized, or
- damage when the plant is undersized.

In ac systems the steady-state voltages and currents are modeled by sinusoidal waveforms. An ac voltage is modeled as: $v(t) = VPcos(\omega t + \theta)$ When equation is plotted, the result is shown in fig.

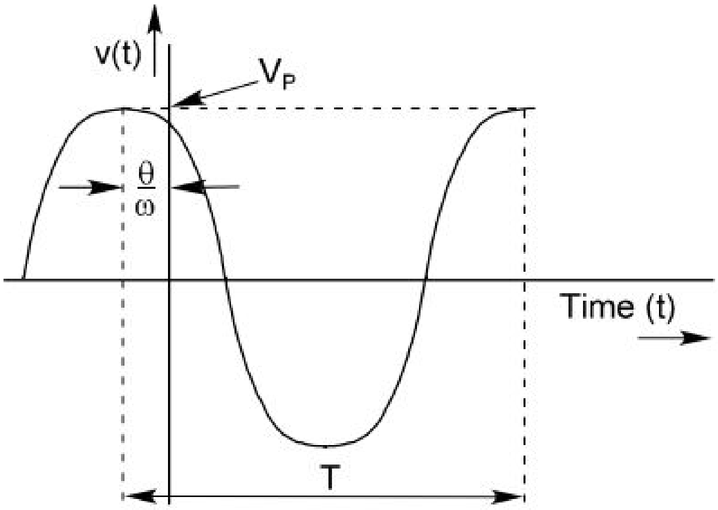

Figure . A sinusoidal voltage in steady-state

The quantities being modeled are:

- VP is the peak voltage.
- ω is the frequency in radians per second (rad/s), $\omega = 2\pi f$.
- f is the frequency in hertz (Hz), which are cycles per second, $f = 1/T$.
- T is the periodic time of the oscillations, $T = 2\pi / \omega$
- θ is the phase angle and allows for the fact that the waveform may not be zero or maximum when

t = 0. The phase angle is shown in figure 1 for a waveform modeled by a cosine wave, since it is measured from the maximum.

ω is constant and if all waveforms are modeled as cosine waves then the only information that has to be conveyed from equation is VP and θ, which can be put into vector form as: VP = VP/θ .

Video Content / Details of website for further learning (if any):

https://youtu.be/ju_GcrFjVPM
https://youtu.be/H1YHyJRBxs8
https://youtu.be/dRhShv4rEiQ

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:477.

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LECTURE HANDOUTS | **L 11**

ECE | **II / III**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS** **Date of Lecture:**

Topic of Lecture: Forced Response to Sinusoidal functions

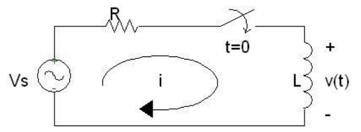
Introduction : The forced response is what the circuit does with the sources turned on, but with the initial conditions set to zero. The natural response is what the circuit does including the initial conditions, but with the input suppressed. The total response is the sum of the forced response plus the natural response.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **sine wave**
2. **response**
3. **sources**
4. **frequency**

Detailed content of the Lecture:

The sinusoidal response of a system refers to its response to a sinusoidal input: u(t)=cosω0t or u(t)=sinω0t. To characterize the sinusoidal response, we may assume a complex exponential input of the form: u(t)=ejω0t, u(s)=1s−jω0. Then, the system output is given as: y(s)=G(s)s−jω0. If we consider the circuit:



which is the same as the circuit in the step response but this time the source is sinusoidal where:

$$V_s = V_0 \cos\omega_0 t$$

Thus applying kirchoff's voltage law, summing up the voltages in the loop:

$$V_0 \cos\omega_0 t = L\frac{di}{dt} + iR$$

The complementary function of this differential equation is

$$i(t) = Ae^{-\frac{R}{L}t}$$

As the driving function is sinusoidal it is not unreasonable to assume that the response will be sinusoidal but we will not know the phase or the amplitude. Thus we can use the following to find the particular integral:

$$i(t) = D\cos\omega_0 t + E\sin\omega_0 t$$

and the derivative of this is:

$$\frac{di}{dt} = -\omega_0 D \sin\omega_0 t + \omega_0 E \cos\omega_0$$

hence substituting these into the differential equation we obtain:

$$-\omega_0 LD \sin\omega_0 t + \omega_0 LE \cos\omega_0 t + RD\cos\omega_0 t + RE \sin\omega_0 t = V_m \cos\omega_0 t$$

then grouping the coefficients of the cosines and sines together we obtain the two simultaneous equation. These can then be solved to provide values of D and E as follows:

$$D = \frac{RV_0}{(R^2 + \omega_0{}^2 L^2)} \qquad E = \frac{\omega_0 LV_0}{(R^2 + \omega_0{}^2 L^2)}$$

this then gives us:

$$i(t) = \frac{RV_0}{(R^2 + \omega_0{}^2 L^2)} \cos\omega_0 t + \frac{\omega_0 LV_0}{(R^2 + \omega_0{}^2 L^2)} \sin\omega_0 t + Ae^{-\frac{R}{L}t}$$

$$\Rightarrow \frac{V_0}{(R^2 + \omega_0{}^2 L^2)}(R\cos\omega_0 t + \omega_0 L \sin\omega_0 t) + Ae^{-\frac{R}{L}t}$$

with just *A* to be found. This is done by considering the initial conditions. When the switch is closed it is assumed that there is no energy already stored in the inductor hence there is no current in the circuit. So evaluating the above when *t=0* gives

$$A = -\frac{V_0 R}{R^2 + \omega_0^2 L^2}$$

hence the above formula becomes:

$$i(t) = \frac{V_0}{(R^2 + \omega_0{}^2 L^2)}(R\cos\omega_0 t + \omega_0 L \sin\omega_0 t - Re^{-\frac{R}{L}t})$$

Video Content / Details of website for further learning (if any):

https://youtu.be/LOyN_-8mYSI
https://youtu.be/r_SLOdEKvkc

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:478.

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LECTURE HANDOUTS **L 12**

ECE **II / III**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS** **Date of Lecture:**

Topic of Lecture: Phasor Relationship for passive components

Introduction :

Many a time, alternating voltages and currents are represented by a sinusoidal wave, or simply a sinusoid. It is a very common type of alternating current (ac) and alternating voltage. The sinusoidal wave is generally referred to as a sine wave. Basically, an alternating voltage (current) waveform is defined as the voltage (current) that fluctuates with time periodically, with change in polarity and direction. In general, the sine wave is more useful than other waveforms, like pulse, sawtooth, square, etc.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Inductor**
2. **Force**
3. **Conductor**
4. **Magnetic field**

Detailed content of the Lecture:

the voltage current relation in the case of an inductor is given by

$$v(t) = L\frac{di}{dt}$$

Consider the function $i(t) = I_m \sin\omega t = IM\left[I_m e^{j\omega t}\right]$ or $I_m\angle 0°$

$$v(t) = L\frac{d}{dt}(I_m \sin\omega t)$$

$$= L\omega I_m \cos\omega t = \omega L I_m \cos\omega t$$

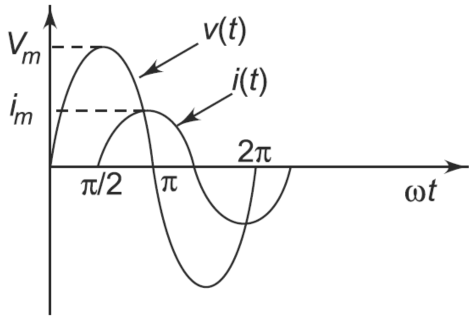
$$v(t) = V_m \cos\omega t, \quad \text{or} \quad V_m \sin(\omega t + 90°)$$

$$= IM\left[V_m e^{j(\omega t + 90°)}\right] \quad \text{or} \quad V_m\angle 90°$$

where $V_m = \omega L I_m = X_L I_m$

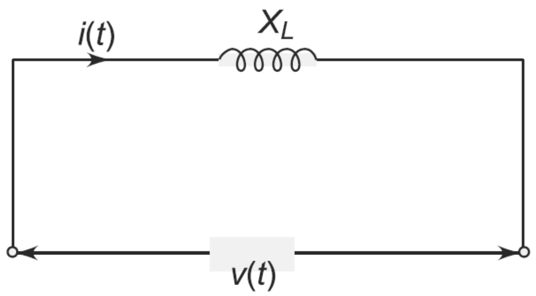
and $e^{j90°} = j = 1\angle 90°$

if we draw the waveforms for both, voltage and current, as shown in Fig, we can observe the phase difference between these two waveforms.



As a result, in a pure inductor the voltage and current are out of phase. The current lags behind the voltage by 90° in a pure inductor as shown in Fig

The impedance which is the ratio of exponential voltage to the corresponding current, is given



$$Z = \frac{V_m \sin(\omega t + 90^\circ)}{I_m \sin \omega t}$$

$$\text{where} \quad V_m = \omega L\, I_m$$

$$= \frac{I_m \omega L \sin(\omega t + 90^\circ)}{I_m \sin \omega t}$$

$$= \frac{\omega L\, I_m \angle 90^\circ}{I_m \angle 0^\circ}$$

$$\therefore \quad Z = j\omega L = jX_L$$

where XL 5 ωL and is called the inductive reactance.
Hence, a pure inductor has an impedance whose value is ωL.

Video Content / Details of website for further learning (if any):

https://youtu.be/t2qDPfk8f8M

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:174 to 177

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LECTURE HANDOUTS | **L 13**

ECE | **II / III**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS** **Date of Lecture:**

Topic of Lecture: Impedance and Admittance

Introduction : Admittance is defined as a measure of how easily a circuit or device will allow current to flow through it. Admittance is the reciprocal (inverse) of impedance, akin to how conductance and resistance are related. The SI unit of admittance is the siemens (symbol S).

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Resistor**
2. **Capacitor**
3. **Inductor**

Detailed content of the Lecture:

Impedance is the resistive parameter offered to the flow of current in a circuit. Whenever current flows or electrons move through a closed circuit, due to collisions of electrons, resistance is offered to the flow of current.

In a DC circuit, impedance is nothing but resistance. But in an AC circuit, along with resistance, inductance and capacitance are also present. Inductance occurs due to change in current which creates a magnetic field around the conductor. Due to this magnetic field, an opposition is offered to the change in current which is termed as inductance. Capacitance is due to the electric field of the current. Capacitance offers resistance to the change in voltage.

We define impedance, Z, as

$Z = R + j*(\omega L + 1/\omega C)$

Where w is the angular frequency of supply, L is the self inductance and C is the capacitance.

the Impedance and Admittance Triangle using which one can get the value of Impedance and Admittance.

Admittance, Y, is the reciprocal of impedance.

We define Y as, Y = 1/Z

Y = G + jB

G is the conductance and B is the susceptance.

The synonymous unit of Admittance is mho, and the symbol ℧ (an upside-down uppercase omega Ω), are also in common use.

Normally we take impedance for series circuit to express voltage in terms of current. Admittance is taken in case of parallel circuit to express current in terms of voltage.

Admittance is defined as. where Y is the admittance, measured in siemens Z is the impedance, measured in ohms. Resistance is a measure of the opposition of a circuit to the flow of a steady current, while impedance takes into account not only the resistance but also dynamic effects (known as reactance).

Impedance and resistance both have applications whether you consider it or not, both exist in your own house. Your house's electricity is controlled by a panel that has fuses in it. When you go through an electrical surge, the fuses are there to interrupt the power so that the injury is minimized. Your fuses are similar to very high-capacity resistors that are capable of taking the blow. Without them, your house's electrical system would fry and you would have to make it up from scratch

This problem can be solved thanks to impedance and resistance. Another situation in which impedance has importance is in capacitors. In capacitors, impedance is used to manage the flow of electricity in a circuit board. Without the capacitors controlling and adaptable electrical flow, your electronics that use alternating currents will either fry or go berserk. Since alternating current delivers electricity at a fluctuating pulse, there needs to be a gate that holds back all the electricity and lets it go smoothly so that the electrical circuit is not overloaded or under loaded.

Video Content / Details of website for further learning (if any):

https://youtu.be/xKNv2gXYzlk

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:177

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LECTURE HANDOUTS

L 14

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS**

Date of Lecture:

Topic of Lecture: Application of network theorems

Introduction : The current through, or voltage across, any element of a **network** is equal to the algebraic sum of the currents or voltages produced independently by each source. In other words, this **theorem** allows us to find a solution for a current or voltage using only one source at a time.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Resistor**
2. **kirchhoff's voltage law**
3. **kirchhoff's current law**

Detailed content of the Lecture:

Application of Superposition Theorem -

- When the several e.m.f. sources are of the same frequency- then, find the algebraic sum.
- When they are of different frequency - then, find their r.m.s. addition.
- Can be used for D.C. and transient e.m.f.s, provided the circuit elements are linear.

Application Of Thevenin Theorem

- It is very useful for analyzing power systems and other circuits where one particular

load resistor in the circuit and re-calculation of the circuit is essential with each trial value of load resistance, to find the voltage across it and current through it.

The limitations for Thevenin's theorem are:

- This theorem is applicable only for linear, bilateral networks.
- This theorem is valid only for a certain range, because it is applicable for linear circuits only.

Application Of Norton’sTheorem

- The Norton equivalent circuit is used to represent any network of linear sources and impedances at a given frequency. Norton's theorem and its dual, Thévenin's theorem, are widely used for circuit analysis simplification and to study circuit's initial-condition and steady-state response.

Application Of Maximum power transfer theorem Theorem

- Maximum power transfer theorem is applied on the public address system where the circuit is make in order to create maximum power transfer with the help of making speaker and amplifier equal to each other.
- It is also applicable on car engine where power needed for the motor starter will depend on the motor resistance as well as the battery resistance , on equaling of these resistance power transferred toward engine will be maximum.
- It is also help in making a circuit having maximum power dissipation correctly at the load of resistance.

Application Of Reciprocity theorem

- This theorem is applied to analyze Ultrasound Generated by High-Intensity Surface Heating of Elastic Bodies. This theorem is applied to determine line-load-generated surface waves on an inhomogeneous transversely isotropic half-space

Application Of tellegen's theorem

- The classical application area for network theory and Tellegen's theorem is electrical

circuit theory. It is mainly in use to design filters in signal processing applications.

- A more recent application of Tellegen's theorem is in the area of chemical and

biological processes. The assumptions for electrical circuits (Kirchhoff laws) are generalized for dynamic systems obeying the laws of irreversible thermodynamics. Topology and structure of reaction networks (reaction mechanisms, metabolic networks) can be analyzed using the Tellegen theorem.

Application Of Millman's theorem

- **It is very con**venient for determining the voltage across a set of parallel branches, where there are enough voltage source present solution via regular series – parallel reduction method.
- **Its is** mostly applied for circuits with several operational amplifiers representing complex circuit topology.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=AUeCB5Iy5fA
https://www.youtube.com/watch?v=saVHfHO_CFU

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:115 to 130.

Course Faculty

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LECTURE HANDOUTS | **L 15**

ECE | **II / III**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS** **Date of Lecture:**

Topic of Lecture: Instantaneous Power Analysis

Introduction : In a purely resistive circuit, all the energy delivered by the source is dissipated in the form of heat by the resistance. In a purely reactive(inductive or capacitive) circuit, all the energy delivered by the source is stored by the inductor or capacitor in its magnetic or electric field during a portion of the voltage cycle, and then is returned to the source during another portion of the cycle, so that no net energy is transferred. When there is complex impedance in a circuit, a part of the energy is alternately stored and returned by the reactive part, and part of it is dissipated by the resistance.

Prerequisite knowledge for Complete understanding and learning of Topic:

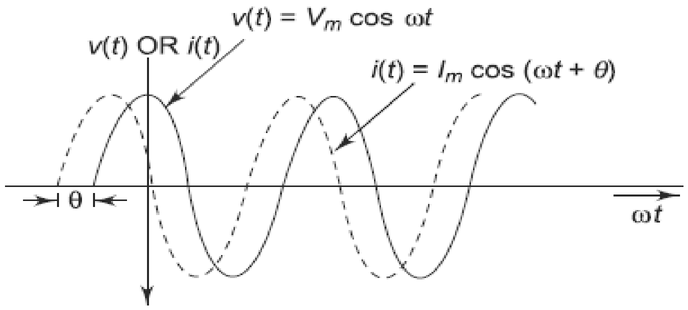
1. **Resistor**
2. **Power**
3. **kirchhoff's law**

Detailed content of the Lecture:

Consider a circuit having complex impedance. Let v (t) = Vm cos ωt be the voltage applied to the circuit and let i(t) = Im cos (ωt +θ) be the corresponding current flowing through the circuit. Then the power at any instant of time is

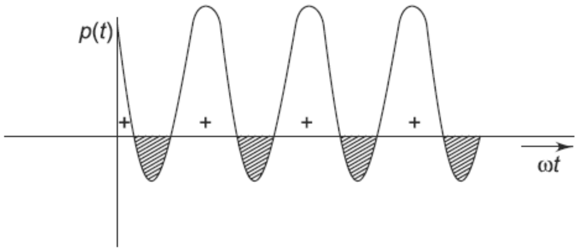
P(t) =v (t) i (t)

=Vm cos ωt Im cos (ωt + θ)



P (t)=Vm Im/2 [cos (2ω+θ)+cosθ]

It consists of two parts. One is a fixed part, and the other is time-varying which has a frequency twice that of the voltage or current waveforms. The voltage, current and power waveforms are shown in Figs.



Here, the negative portion (hatched) of the power cycle represents the power returned to the source. Figure shows that the instantaneous power is negative whenever the voltage and current are of opposite sign. In Fig. the positive portion of the power is greater than the negative portion of the power; hence, the average power is always positive, which is almost equal to the constant part of the instantaneous power. The positive portion of the power cycle varies with the phase angle between the voltage and current waveforms. If the circuit is pure resistive, the phase angle between voltage and current is zero; then there is no negative cycle in the P (t) curve. Hence, all the power delivered by the source is completely dissipated in the resistance. If u becomes zero in Eq, we get

$$P(t) = v(t)\, i(t)$$
$$= V_m I_m \cos^2 \omega t$$
$$= V_m I_m/2\, [1+\cos 2\omega t]$$

The waveform for Eq, is shown in Fig. , where the power wave has a frequency twice that of the voltage or current. Here, the average value of power is Vm Im /2. When phase angle u is increased, the negative portion of the power cycle increases and lesser power is dissipated.
When u becomes p/2, the positive and negative portions of the power cycle are equal. At this instant, the power dissipated in the circuit is zero, i.e. the power delivered to the load is returned to the source.

Video Content / Details of website for further learning (if any):

https://youtu.be/IST5IV-fPtQ
https://youtu.be/If25y4Nhvw4

Important Books/Journals for further learning including the page nos.:
A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:221.

Course Faculty

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LECTURE HANDOUTS | **L 16**

ECE | **IV / VII**

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS** **Date of Lecture:**

Topic of Lecture: Average and RMS

Introduction : The **average** of all the instantaneous **values** of an alternating voltage and currents over one complete cycle is called **Average Value**. If we consider symmetrical waves like sinusoidal current or voltage waveform, the positive half cycle will be exactly equal to the negative half cycle.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **voltage**
2. **current**
3. **power**

Detailed content of the Lecture:

- The **RMS value** is defined as the square root of the mean **value** of the squared function. This is often used as the effective d.c. **voltage** (or current) of an a.c. **voltage** (or current). This **value** can then be used in the calculation of the average power of an AC waveform.
- To find the average value of any power function, we have to take a particular time interval from t1 to t2; by integrating the function from t1 to t2 and dividing the result by the time interval t2 – t1, we get the average power.

$$\text{Average power } P = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} P(t)\,dt$$

In general, the average value over one cycle is

$$P_{av} = \frac{1}{T}\int_{0}^{T} P(t)\,dt$$

By integrating the instantaneous power P(t) over one cycle, we get average power

$$P_{av} = \frac{1}{T}\int_0^T \left\{\frac{V_m I_m}{2}[\cos(2\omega t+\theta)+\cos\theta]dt\right\}$$

$$= \frac{1}{T}\int_0^T \frac{V_m I_m}{2}[\cos(2\omega t+\theta)]dt + \frac{1}{T}\int_0^T \frac{V_m I_m}{2}\cos\theta dt$$

The first term becomes zero, and the second term remains. The average power is therefore

$$P_{av} = \frac{V_m I_m}{2}\cos\theta \text{ W}$$

We can write Eq.

$$P_{av} = \left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right)\cos\theta$$

Vm / √ 2 and Im / √2 are the effective values of both voltage and current.

Pav $=V_{eff} I_{eff} \cos\theta$

To get average power, we have to take the product of the effective values of both voltage and Current multiplied by cosine of the phase angle between voltage and the current.

If we consider a purely resistive circuit, the phase angle between voltage and current is zero. Hence, the average power is

P av=1/2 V m I m = 1/2 I^2 mR

If we consider a purely reactive circuit (i.e. purely capacitive or purely inductive), the phase angle between voltage and current is 90°. Hence, the average power is zero or Pav 5 0.

If the circuit contains complex impedance, the average power is the power dissipated in the resistive part only.

Video Content / Details of website for further learning (if any):

https://youtu.be/KygtYb2EsQE
https://youtu.be/qDHsokTcgck
https://youtu.be/LuLJfItMqyc

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:222.

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Course Name with Code : ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS

Date of Lecture:

Topic of Lecture: Power and Power factor

Introduction : the power factor of an AC electrical power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit, and is a dimensionless number in the closed interval of −1 to 1.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Passive component**
2. **kirchhoff's voltage law**
3. **kirchhoff's current law**

Detailed content of the Lecture:

- The power factor is useful in determining useful power (true power) transferred to a load. The highest power factor is 1, which indicates that the current to a load is in phase with the voltage across it (i.e. in the case of resistive load). When the power factor is 0, the current to a load is 90° out of phase with the voltage (i.e. in case of reactive load).

Consider the following equation:

$$P_{av} = \frac{V_m I_m}{2} \cos\theta \text{ W}$$

In terms of effective values,

$$P_{av} = \left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right)\cos\theta$$

$$= V_{eff}\, I_{eff} \cos\theta \text{ W}$$

The average power is expressed in watts. It means the useful power transferred from the source to the load, which is also called true power. If we consider a dc source applied to the network, true power is given by the product of the voltage and the current. In case of sinusoidal voltage applied to the circuit, the product of voltage and current is not the true power or average power. This product is called apparent power. The apparent power is expressed in volt amperes, or simply VA.

Apparent power= $V_{eff}\ I_{eff}$

the average power depends on the value of cos u; this is called the power factor of the circuit.

Power factor (pf)= $\cos\theta = P_{av} / V_{eff}\ I_{eff}$

Therefore, power factor is defined as the ratio of average power to the apparent power, whereas apparent power is the product of the effective values of the current and the voltage. Power factor is also defined as the factor with which the volt amperes are to be multiplied to get true power in the circuit.

In the case of sinusoidal sources, the power factor is the cosine of the phase angle between voltage and current

Pf= $\cos\theta$

As the phase angle between voltage and total current increases, the power factor decreases. The smaller the power factor, the smaller the power dissipation.

The power factor varies from 0 to 1. For purely resistive circuits, the phase angle between voltage and current is zero, and hence the power factor is unity.

For purely reactive circuits, the phase angle between voltage and current is 90°, and hence the power factor is zero.

In an RC circuit, the power factor is referred to as leading power factor because the current leads the voltage.

In an RL circuit, the power factor is referred to as lagging power factor because the current lags behind the voltage.

Video Content / Details of website for further learning (if any):

https://youtu.be/AgPWpXPKeOo
https://youtu.be/k8JSmvYavyM

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:225.

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LECTURE HANDOUTS

L 18

ECE

II / III

Course Name with Code : **ELECTRIC NETWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **II – SINUSOIDAL AND STEADY STATE POWER ANALYSIS**

Date of Lecture:

Topic of Lecture: Magnetically Coupled Circuits.

Introduction : Two circuits are said to be 'coupled' when energy transfer takes place from one circuit to the other when one of the circuits is energised. There are many types of couplings like conductive coupling as shown by the potential divider inductive or magnetic coupling as shown by a two-winding transformer or conductive and inductive coupling as shown by an auto transformer. A majority of the electrical circuits in practice are conductively or electromagnetically coupled. Certain coupled elements are frequently used in network analysis and synthesis.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Inductor**
2. **Magnetic field**
3. **Energy**

Detailed content of the Lecture:

self-inductance

A voltage is induced in a coil when there is a time rate of change of current through it. The inductance parameter L, is defined in terms of the voltage across it and the time rate of change of current through it $v(t) = L\, di(t)/ dt$, where v(t) is the voltage across the coil, I(t) is the current through the coil and L is the inductance of the coil. his definition is of self-inductance.

Mutual Inductor

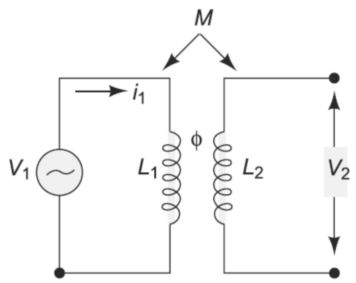
This is considered as a circuit element with a pair of terminals. Mutual inductance is a property associated with two or more coils or inductors which are in close proximity and the presence of common magnetic flux which links the coils. A transformer is such a device whose operation is based on mutual inductance

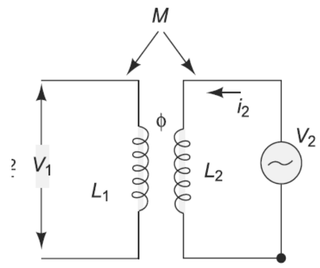
Let us consider two coils, L1 and L2, which are sufficiently close together, so that the flux produced by i1 in the coil L1 also link the coil L2. We assume that the coils do not move with respect to one another, and the medium in which the flux is established has a constant permeability.

The two coils may be also arranged on a common magnetic core, The two coils are said to be magnetically coupled, but act as a separate circuits. It is possible to relate the voltage induced in one coil to the time rate of change of current in the other coil. When a voltage v1 is applied across L1, a current i1 will start flowing in this coil, and produce a flux f.

This flux also links the coil L2. If i1 were to change with respect to time, the flux 'f' would also change with respect to time. The time-varying flux surrounding the second coil, L2 induces an emf, or voltage, across the terminals of L2; this voltage is proportional to the time rate of change of current flowing through the first coil L1.

The two coils, or circuits, are said to be inductively coupled, because of this property they are called coupled elements or coupled circuits and the induced voltage, or emf is called the voltage/emf of mutual induction and is given by $v_2(t)= M_1 di_1(t) / dt$ volts, where v_2 is the voltage induced in coil L2 and M1 is the coefficient of proportionality, and is called the coefficient of mutual inductance, or simple mutual inductance.





If current i2 is made to pass through coil L2, with coil L1 open, a change of i2 would cause a voltage v1 in coil L1, given by v 1 (t) = M2 di2(t)/dt In the above equation, another coefficient of proportionality M2 is involved. Though it appears that two mutual inductances are involved in determining the mutually induced voltages in the two coils, it can be shown from energy considerations that the two coefficients are equal and, therefore, need not be represented by two different letters. Thus, M1 =M2 =M.

Video Content / Details of website for further learning (if any):

https://youtu.be/Ov0AO3zciUI
https://youtu.be/sILgO4sQmRs

Important Books/Journals for further learning including the page nos.:

A Sudhakar, Shyammohan S Palli, Circuits and Networks Analysis and Synthesis Fifth Edition,2015, Page no:413 to 419.

Course Faculty

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LECTURE HANDOUTS

L 19

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Complex Frequency

Introduction : A type of frequency that depends on two parameters; one is the 'σ' which controls the magnitude of the signal and the other is 'w', which controls the rotation of the signal; is known as 'complex frequency'.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **voltage**
2. **current**
3. **active and passive component**

Detailed content of the Lecture:

The solution of differential equations for networks is of the form

$$i(t) = K_n \; e^{S_n t}$$

where Sn is a complex number which is a root of the characteristic equation and may, therefore, be expressed as

$$S_n = \sigma_n + j\omega_n$$

The complex number consists of two parts, the real part σn and the imaginary part ωn. The real part of the complex frequency σn is neper frequency, while the imaginary part ωn is the radian frequency. The neper frequency has dimensions of neper per second. In the time-domain equations, ωn is in the form of sin ωnt or cos ωnt. The radian frequency ωn is expressed in radians/second and is related to the frequency fn in cycles/ sec or the periodic time T (in seconds) by the relation.

$$\omega_n = 2\pi f_n = \frac{2\pi}{T}$$

we see that the real part σn and the imaginary part ωn must have identical dimensions.
Radian frequency ωn is 2π/T has dimensions (time)-1. Therefore, the dimensions of σn must also be (time)–1 or the unit of σn must be "something per unit time". Since σn appears as an

exponential factor,

$$I = I_0 e^{\sigma_n t}$$

Such that

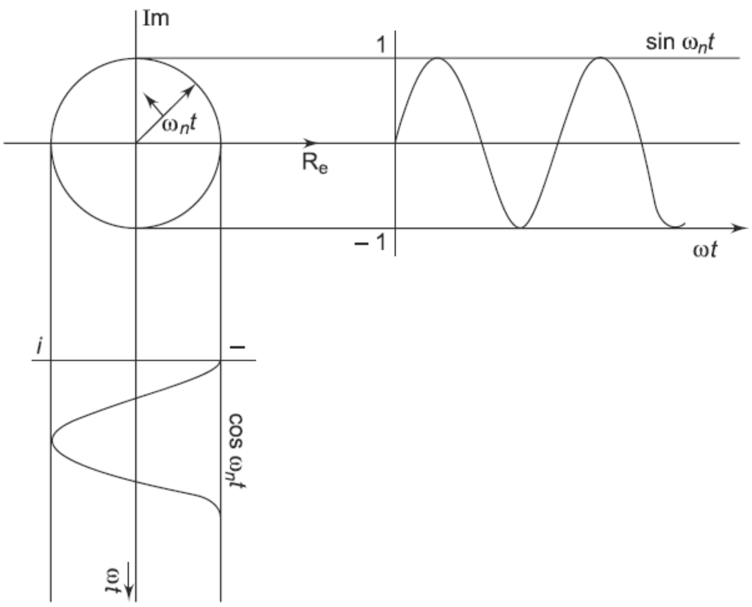
$$\sigma_n = \frac{1}{t}\ln\left(\frac{I}{I_0}\right)$$

It is fact that "something per unit time" should be nondimensional logarithmic unit. The usual unit for the natural logarithm is the neper, making the dimensions for σ the neper per second. The complex quantity

$$S_n = \sigma_n + j\omega_n$$

is defined as the complex frequency. Thus, complex frequency consists of a real part σn called the neper frequency and an imaginary part ωn is called radian frequency (or real frequency).

S-Domain Analysis



Video Content / Details of website for further learning (if any):

https://youtu.be/2A8lIVTvHFs
https://youtu.be/8QFwB0M7Ig8

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:533 to 540

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LECTURE HANDOUTS

L 20

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Damped Sinusoidal Forcing Function

Introduction : If the convolution system is stable, the response to a sinusoidal input is asymptotically sinusoidal, with the same frequency as the input, and with magnitude & phase determined by H(jω)

- |H(jω)| gives amplification factor, i.e., RMS(yss)/RMS(u)

H(jω) gives phase shift between u and yss

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **sources**
2. **voltage**
3. **current**

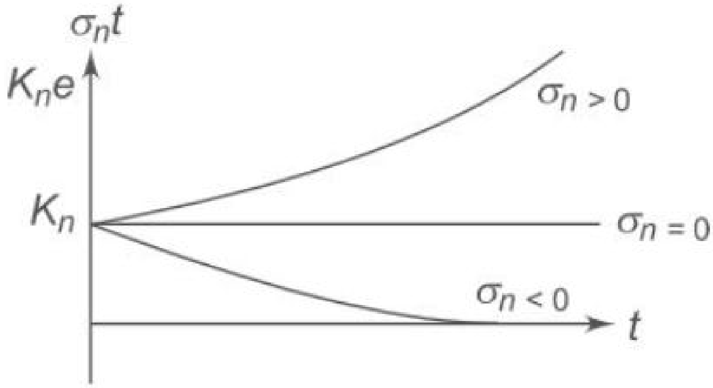
Detailed content of the Lecture:

The complex frequency appears in the exponential form e^S n t . Let us consider the physical significance of complex frequency and a number of special cases for the values of Sn.

Case(i)‰ Let Sn = σn +jω having zero radian frequency. The exponential function becomes

Kn e^Snt = Kn$e^σ$nt

The above exponential function increases exponentially for σn >0 and decreases exponentially for σn <0. For sn = 0, the exponential function reduces to Kn and it is a time-invariant resulting current i(t) which is a dc current. Fig. the variation of exponential term Kn eσnt with time t for the cases of σn >0, σn <0 and σn = 0.



Case‰(ii)‰Let Sn = 0 ±jωn having radian frequency and zero neper frequency. The exponential becomes

$$i(t) = K_n e^{\pm j\omega_n t}$$
$$= K_n (\cos \omega_n t \pm j \sin \omega_n t)$$

The exponential e±jωnt may be interpreted in terms of the physical model of a rotating phasor of unit length. A positive sign of exponential e±jωnt implies counter- clockwise or positive rotation, while a negative sign e–jωnt implies clockwise or negative rotation.

For positive or counter-clockwise rotation, the real part of e+jωnt or the projection on the real axis equals cos ωnt, while the imaginary part of e+jωnt or the projection on the imaginary axis equals sin ωnt. The variation of exponential function e+jωnt with time is thus sinusoidal and hence constitutes the case of sinusoidal steady state.

Case%(iii)‰Let Sn = σn + jωn is the general case and the frequency is complex and the exponential is given by

$$i(t) = K_n e^{S_n t} = K_n e^{(\sigma_n + j\omega_n)t}$$
$$i(t) = K_n e^{\sigma_n t} \cdot e^{j\omega_n t}$$

shows that with complex frequency, the time variation of response i(t) is the product of the response for Sn = σn + jo and the response for Sn = 0 + jωn. The response eσnt for the case of neper frequency alone, Sn = σn + jo is an exponentially increasing or decaying function. The response ejωnt for the case of radian frequency alone Sn = 0 + jωn may be represented by a rotating phasor. The product eσnt* e j ω n t may then be visualized as a rotating phasor whose magnitude is not constant at unity but changes continuously with time.

Video Content / Details of website for further learning (if any):

https://youtu.be/hkTI-bmL7ZE
https://youtu.be/LbVL5O_bG9w

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:573 to 580

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LECTURE HANDOUTS

L 21

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Introduction To Laplace Transform

Introduction : The Laplace transform is a particularly elegant way to solve linear differential equations with constant coefficients. The Laplace transform describes signals and systems not as functions of time, but as functions of a complex variable.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **ohm's law**
2. **voltage law**
3. **current law**

Detailed content of the Lecture:

Laplace Transform:

In circuit analysis, the input and output functions do not exist forever in time. For causal functions, the function can be defined as f (t) u(t). The integral for the Laplace transform is taken with the lower limit at t = 0 in order to include the effect of any discontinuity at t = 0.

Consider a function f (t) which is to be continuous and defined for values of t ≥ 0. The Laplace transform is then

$$\mathcal{L}[f(t)] = F(s) = \int_{-\infty}^{\infty} e^{-st} f(t)\, u(t)\, dt = \int_{0}^{\infty} f(t) e^{-st}\, dt$$

f (t) is a continuous function for t ≥ 0 multiplied by e^{-st} which is integrated with respect to t between the limits 0 and ∞. The resultant function of the variables is called Laplace transform of f (t). Laplace transform is a function of independent variable s corresponding to the complex variable in the exponent of e–st. The complex variable S is, in general, of the form S = σ + jω and σ and ω being the real and imaginary parts respectively. For a function to have a Laplace transform, it must satisfy the condition

$$\int_{0}^{\infty} f(t) e^{-st} dt < \infty.$$

Laplace transform changes the time-domain function f (t) to the frequency-domain function F(s).

Similarly,
The inverse Laplace transformation converts frequency-domain function F(s) to the time-domain function f (t) as follows.

$$\mathcal{L}^{-1}[F(s)] = f(t) = \frac{1}{2\pi j}\int_{-j}^{+j} F(s)\, e^{st}\, ds$$

Here, the inverse transform involves a complex integration. f (t) can be represented as a weighted integral of complex exponentials. We will denote the transform relationship between f (t) and F(s) as

$$f(t) \xleftrightarrow{\mathcal{L}} F(s)$$

If the lower limit is 0 then the transform is referred to as one-sided, or unilateral, Laplace Transform. In the two-sided, or bilateral, Laplace transform, the lower limit is – ∞.
In the following discussion, we divide the Laplace transforms into two types: functional transforms and operational transforms. A functional transform is the Laplace transform of a specific function, such as sinωt, t, e-at, and so on. An operational transform defines a general mathematical property of the Laplace transform, such as binding the transform of the derivative of f (t). Before considering functional and operational transforms, we used to introduce the step and impulse functions.

- Step Function
- Impulse Function
- Functional Transforms

Operational Transforms

Video Content / Details of website for further learning (if any):

https://youtu.be/1wWiA0l2GQk
https://youtu.be/v5d5tanLZaA

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin,” Engineering circuit analysis”Seventh Edition, Page no:540 to 545

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LECTURE HANDOUTS

L 22

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Inverse Transform Techniques

Introduction : Inverse transform sampling is a method for generating random numbers from any probability distribution by using its inverse cumulative distribution F−1(x). Recall that the cumulative distribution for a random variable X is FX(x)=P(X≤x).

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Inductor**
2. **Force**
3. **Conductor**
4. **Magnetic field**

Detailed content of the Lecture:

Laplace transform of a functions f (t). If the function is a rational function of s, which can be expressed in the form of a ratio of two polynomials in s such that no non-integral powers of s appear in the polynomials. In fact, for linear, lumped-parameter circuits whose component values are constant, the s-domain expressions for the unknown voltages and currents are always rational functions of s. If we can inverse transform rational functions of s, we can solve for the time domain expressions for the voltages and currents.

In general, we need to find the inverse transform of a function that has the form.

$$F(s) = \frac{N(s)}{D(s)} = \frac{a_n s^n + a_{n-1} s^{n-1} + \ldots + a_1 s + a_0}{b_m s^m + b_{m-1} s^{m-1} + \ldots + b_1 s + b_0}$$

The coefficients a and b are real constants, and the exponents m and n are positive integers. The ratio N (s)/D (s) is called a proper rational function if m > n, and an improper rational function if m ≤ n. Only a proper rational function can be expanded as a sum of partial fractions.

Partial Fraction Expansion: Proper Rational Functions

A proper rational function is expanded into a sum of partial fractions by writing a term or a series of terms for each root of D(s). Thus, D(s) must be in factored form before we can make a partial fraction expansion. The roots of D(s) are either (1) real and distinct, (2) complex and distinct, (3) real and repeated, or (H) complex and repeated

When the Roots are Real and Distinct

In this case, $F(s) = \frac{N(s)}{D(s)}$

where $D(s) = (s-a)(s-b)(s-c)$

Expanding $F(s)$ into partial fractions, we get

$$F(s) = \frac{A}{s-a} + \frac{B}{s-b} + \frac{C}{s-c}$$

To obtain the constant A, multiplying with (s – a) and putting s=a, we get

$$F(s)\,(s-a)|_{s=a} = A$$

Similarly, we can get the other constants.

$$B = (s-b)\,F(s)|_{s=b}$$

$$C = (s-c)\,F(s)|_{s=c}$$

- **When Roots are Real and Repeated**
- **When Roots are Distinct Complex Roots of D(s)**
- **When Roots are Repeated and Complex of D(S)**

The complex roots always appear in conjugate pairs and that the coefficients associated with a conjugate pair are also conjugate, so that only half the Ks need to be evolved.

Nature of roots	*F(s)*	*f(t)*
Distinct real	$\frac{k}{s+a}$	$Ke^{-at}\,u(t)$
Repeated real	$\frac{k}{(s+a)^2}$	$Kt\,e^{-at}\,u(t)$
Distinct complex	$\frac{k}{s+\alpha-j\beta} + \frac{k^*}{s+\alpha+j\beta}$	$2\lvert k\rvert e^{-\alpha t}\cos(\beta t+\theta)\,u(t)$
Repeated complex	$\frac{k}{(s+\alpha-j\beta)^2} + \frac{k^*}{(s+\alpha+j\beta)^2}$	$2t\lvert k\rvert e^{-\alpha t}\cos(\beta t+\theta)\,u(t)$

Video Content / Details of website for further learning (if any):

https://youtu.be/M9kt5ZSjX_I

https://youtu.be/yz-_EKIzz80

Important Books/Journals for further learning including the page nos.:

W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:540 to 550

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LECTURE HANDOUTS

L 23

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: S-Domain: Impedance and Admittance

Introduction : Circuit analysis techniques in the s-domain are powerful because you can treat a circuit that has voltage and current signals changing with time as though it were a resistor-only circuit. That means you can analyze the circuit algebraically, without having to mess with integrals and derivatives

Prerequisite knowledge for Complete understanding and learning of Topic:

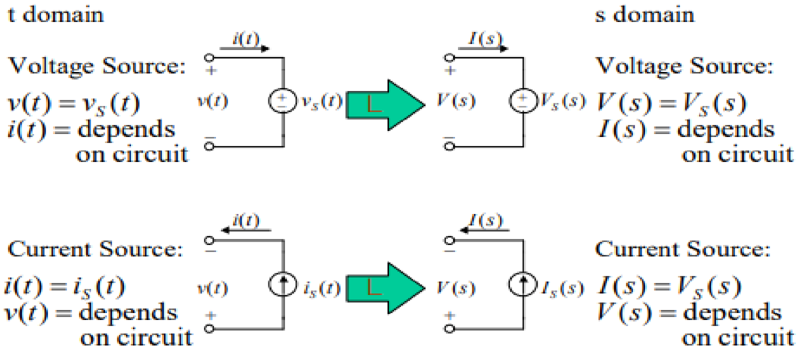
1. **S – Domain**
2. **Impedance**
3. **Admittance**

Detailed content of the Lecture:

S – Domain

A transfer function defines the relationship between the input to a system and its output. It is typically written in the frequency **domain** (**S-domain**), rather than the time **domain** (t-**domain**). The Laplace transform is used to map the time **domain** representation to frequency **domain** representation

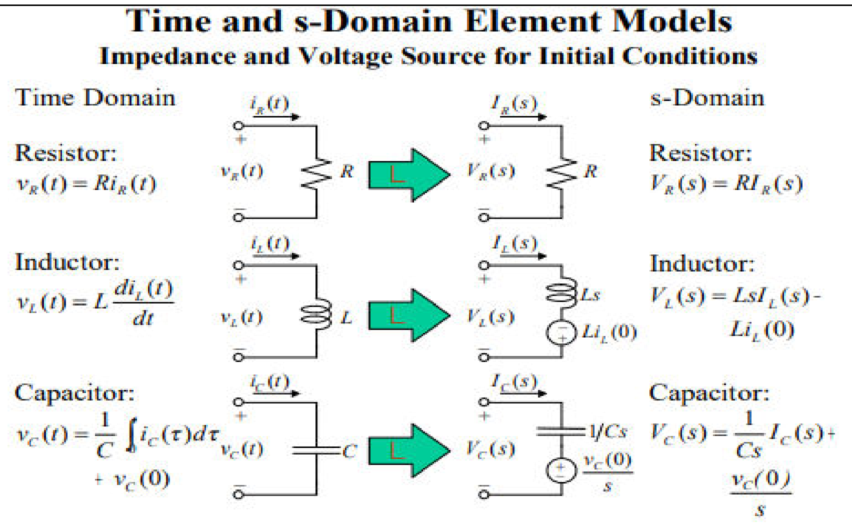
Signal Sources in s Domain



Impedance (Z)

It is the s-domain proportionality factor relating the transform of the voltage across a two-terminal element to the transform of the current through the element with all initial conditions zero

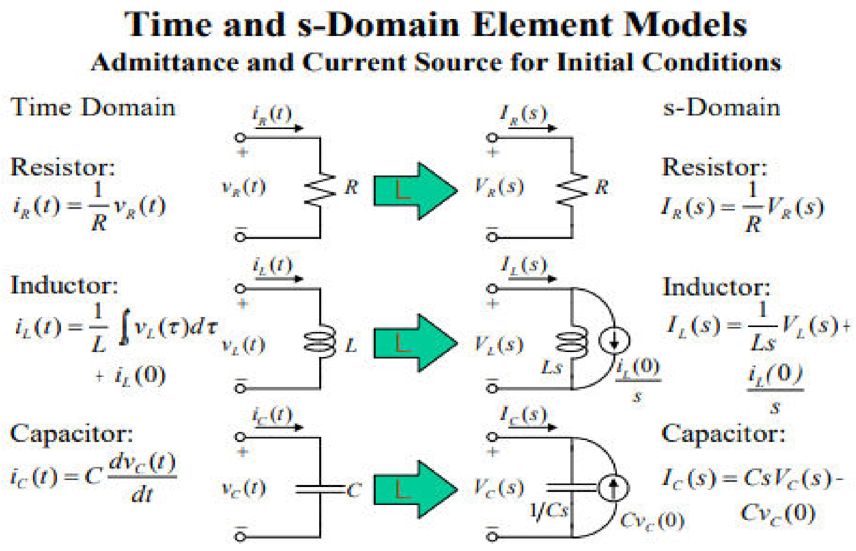
$$V(s) = Z(s)I(s)$$



Admittance (Y)

It is the s-domain proportionality factor relating the transform of the current through a two-terminal element to the transform of the voltage across the element with initial conditions zero

$$I(s) = Y(s)V(s)$$



Video Content / Details of website for further learning (if any):

https://youtu.be/Eh5zvX8pFpQ

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:571 to 577

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LECTURE HANDOUTS

L 24

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis**

Date of Lecture:

Topic of Lecture: Application of Nodal Analysis

Introduction : **Nodal** provide a systematic framework, a form of algebraic equations, to apply Kirchhoff's current and voltage laws to the circuit problem. The time-constants relate to the eigenvalues in time-**domain** and the poles of trans- fer functions in **s-domain**

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Node voltage analysis in s-domain**
2. **Node voltage equation**
3. **Kirchhoff's Law (KCL)**

Detailed content of the Lecture:

Node Voltage Analysis (in s-domain)

- Use Kirchhoff's Current Law (KCL)
- Get equations of node voltages
- Use current sources for initial conditions
- Voltage source current source

Formulating Node-Voltage Equations

Step 1: Transform the circuit into the s domain using current sources to represent capacitor and inductor initial conditions

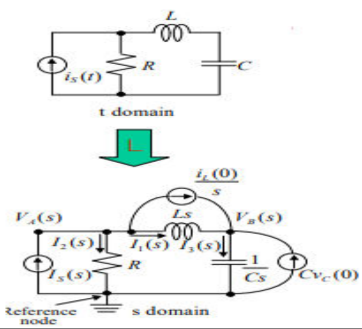
Step 2: Select a reference node. Identify a node voltage at each of the non-reference nodes and a current with every element in the circuit

Step 3: Write KCL connection constraints in terms of the element currents at the non-reference nodes

Step 4: Use the element admittances and the fundamental property of node voltages to express the element currents in terms of the node voltages

Step 5: Substitute the device constraints from Step 3 into the KCL connection constraints from Step 2 and arrange the resulting equations in a standard form

EXAMPLE:



Step 1: Transform the circuit into the s domain using current sources to represent capacitor and inductor initial conditions

Step 2: Identify N-1=2 node voltages and a current with each element

Step 3: Apply KCL at nodes A and B:

$$\text{Node A}: \ I_S(s) - \frac{i_L(0)}{s} - I_1(s) - I_2(s) = 0$$

$$\text{Node B}: \ Cv_C(0) + \frac{i_L(0)}{s} + I_1(s) - I_3(s) = 0$$

Step 4: Express element equations in terms of node voltages

$$I_1(s) = Y_L(s)\left[V_A(s) - V_B(s)\right] = \frac{1}{Ls}\left[V_A(s) - V_B(s)\right]$$

$$I_2(s) = Y_R(s)V_A(s) = GV_A(s) \text{ where } G = 1/R$$

$$I_3(s) = Y_C(s)V_B(s) = CsV_B(s)$$

Step 5: Substitute eqns. in Step 3 into eqns. in Step 2 and collect common terms to yield node-voltage eqns.

$$\text{Node A}: \ \left(G + \frac{1}{Ls}\right)V_A(s) - \left(\frac{1}{Ls}\right)V_B(s) = I_S(s) - \frac{i_L(0)}{s}$$

$$\text{Node B}: \ -\left(\frac{1}{Ls}\right)V_A(s) + \left(\frac{1}{Ls} + Cs\right)V_B(s) = Cv_C(0) + \frac{i_L(0)}{s}$$

Solving s-Domain Circuit Equations

Circuit Determinant

$$\Delta(s) = \begin{vmatrix} G + 1/Ls & -1/Ls \\ -1/Ls & Cs + 1/Ls \end{vmatrix}$$

$$= (G + 1/Ls)(Cs + 1/Ls) - (1/Ls)^2$$

$$= \frac{GLCs^2 + Cs + G}{Ls}$$

Depends on circuit element parameters: L, C, G=1/R, not on driving force and initial conditions

Solve for node A using Cramer's rule:

$$V_A(s) = \frac{\Delta_A(s)}{\Delta(s)} = \frac{\begin{vmatrix} I_S(s) + i_L(0)/s & -1/Ls \\ i_L(0)/s + Cv_C(0) & Cs + 1/Ls \end{vmatrix}}{\Delta(s)}$$

$$= \underbrace{\frac{(LCs^2 + 1)I_S(s)}{GLCs^2 + Cs + G}}_{\substack{\text{Zero State} \\ \text{when initial condition} \\ \text{sources are turned off}}} + \underbrace{\frac{-LCsi_L(0) + Cv_C(0)}{GLCs^2 + Cs + G}}_{\substack{\text{Zero input} \\ \text{when input sources} \\ \text{are turned off}}}$$

Video Content / Details of website for further learning (if any):
https://youtu.be/r9XZWRREC0Y

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:578 to 580

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LECTURE HANDOUTS

L 25

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Application of Mesh Analysis

Introduction : Mesh provide a systematic framework, a form of algebraic equations, to apply Kirchhoff's current and voltage laws to the circuit problem. The time-constants relate to the eigenvalues in time-**domain** and the poles of transfer functions in **s-domain**

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **KVL**
2. **Voltage source**

Detailed content of the Lecture:

Mesh Current Analysis (in s-domain)

- Use Kirchhoff's Voltage Law (KVL)
- Get equations of currents in the mesh
- Use voltage sources for initial conditions
- Current source voltage source

Video Content / Details of website for further learning (if any):
https://youtu.be/nO4rOteH60s

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:578 to 580

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LECTURE HANDOUTS | **L 26**

ECE | **II / III**

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Concept of Poles and Zeroes

Introduction : The roots of the polynomial in the numerator of F(**s**) are zeros, and the roots of the polynomial in the denominator are **poles**. The **poles** result in F(**s**) blowing up to infinity or being undefined — they're the vertical asymptotes and holes in your graph. The transfer function is a key concept in signal processing because it indicates how a signal is processed as it passes through a network

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Poles**
2. **Zeros**

Detailed content of the Lecture:

Poles and Zeros

In analyzing the frequency response of an amplifier, most of the work involves finding the amplifier voltage gain as a function of the complex frequency s. In this s-domain analysis, a capacitance C is replaced by an admittance sC, or equivalently an impedance 1/sC, and an inductance L is replaced by an impedance sL. Then, using usual circuit-analysis technique

$$T(s) = a_m \frac{(s-Z_1)(s-Z_2)\ldots(s-Z_m)}{(s-P_1)(s-P_2)\ldots(s-P_n)}$$

- am is a multiplicative constant (the coefficient of sm in the numerator)
- Z1, Z2, ..., Zm are the roots of the numerator polynomial
- P1,P2, ...,Pn are the roots of the denominator polynomial
- Z1,Z2, ...,Zm are called the transfer-function zeros or transmission zeros

- P1,P2, ...,Pn are the transfer-function poles or the natural modes

The poles and zeros can be either real or complex numbers

- since the a and b coefficients are real numbers, the complex poles (or zeros) must occur in conjugate pairs.
- That is, if 5+j3 is a zero, then 5 – j3 also must be a zero. A zero that is purely imaginary (±jωZ) causes the transfer function T(jω) to be exactly zero at ω=ωZ.
- This is because the numerator will have the factors(s+jωZ)(s−jωZ)=(s2+ω2Z),which for physical frequencies becomes (−ω2+ω2 Z), and thus the transfer fraction will be exactly zero at ω=ωZ.
- Thus the “trap” one places at the input of a television set is a circuit that has a transmission zero at the particular interfering frequency.
- Real zeros, on the other hand, do not produce transmission nulls. Finally, note that for values of s much greater than all the poles and zeros, the transfer function in becomes T(s) am/sn−m. Thus the transfer function has (n−m) zeros at s=∞

Video Content / Details of website for further learning (if any):

https://youtu.be/AZ7_MvANy_Q

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin,” Engineering circuit analysis”Seventh Edition, Page no:588 to 591

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LECTURE HANDOUTS

L 27

ECE

II / III

Course Name with Code : **Electric Network Analysis and Machines & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **III – Application of Laplace Transform To Circuit Analysis** **Date of Lecture:**

Topic of Lecture: Transfer Functions

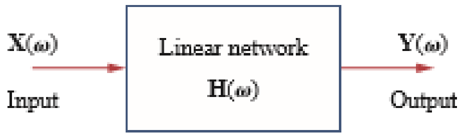
Introduction : In this context, X(ω) and Y(ω) denote the input and output phasors of a network; they should not be confused with the same symbolism used for reactance and admittance. The multiple usage of symbols is conventionally permissible due to lack of enough letters in the English language to express all circuit variables distinctly.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Voltage gain**
2. **Current gain**
3. **Transfer Impedance**
4. **Transfer Admittance**

Detailed content of the Lecture:

- The transfer function H (s) is the ratio of the output response Y (s) to the input excitation X (s), assuming all initial conditions are zero.
- A transfer function is the frequency-dependent ratio of a forced function to a forcing function (or of an output to an input).
- The idea of a transfer function was implicit when we used the concepts of impedance and admittance to relate voltage and current
- It assuming zero initial conditions. Since the input and output can be either voltage or current at any place in the circuit, there are four possible transfer functions



$$H(s) = \frac{Y(s)}{X(s)}$$

- Transfer function of a network describes how the output behaves with respect to the input. It specifies the transfer from the input to the output in the s-domain, assuming no initial energy.

$$H(s) = \text{Voltage gain} = \frac{V_o(s)}{V_i(s)}$$

$$H(s) = \text{Current gain} = \frac{I_o(s)}{I_i(s)}$$

$$H(s) = \text{Impedance} = \frac{V(s)}{I(s)}$$

$$H(s) = \text{Admittance} = \frac{I(s)}{V(s)}$$

- The transfer function can be expressed in terms of its numerator polynomial and denominator polynomial as

$$\mathbf{H}(\omega) = \frac{\mathbf{N}(\omega)}{\mathbf{D}(\omega)}$$

- Where N(ω) and D(ω) are not necessarily the same expressions for the input and output function
- To avoid complex algebra, it is expedient to replace jω temporarily with s when working with H(ω) and replace s with at the end

Video Content / Details of website for further learning (if any):
https://youtu.be/AvaZ_E-nFTk

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin," Engineering circuit analysis"Seventh Edition, Page no:588 to 591

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LECTURE HANDOUTS **L 28**

ECE **II / III**

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK** **DATE OF LECTURE:**

Topic of Lecture: Graph theory: Incidence

Introduction : A division of mathematics called topology or graph theory deals with graphs of networks and provides information that helps in the formulation of network equations. In circuit analysis, all the elements in a network must satisfy Kirchhoff's laws, besides their own characteristics. Based on these laws, we can form a number of equations. These equations can be easily written by converting the network into a graph. Certain aspects of network behaviour are brought into better perspective if a graph of the network is drawn. If each element or a branch of a network is represented on a diagram by a line irrespective of the characteristics of the elements, we get a graph. Hence, network topology is network geometry.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Graph Theory**
2. **Nodes and branch of incidence**

Detailed content of the Lecture:

Graph Theory:

Graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between objects. A **graph** in this context is made up of vertices (also called nodes or points) which are connected by edges

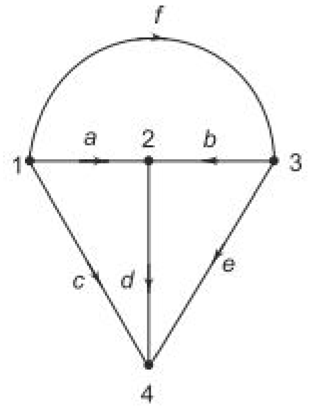
INCIDENCE MATRIX (A)

- The incidence of elements to nodes in a connected graph is shown by the element node incidence matrix (A)
- Arrows indicated in the branches of a graph result in an oriented or a directed graph. These arrows are the indication for the current flow or voltage rise in the network
- It can be easily identified from an oriented graph regarding the incidence of branches to nodes
- It is possible to have an analytical description of an oriented-graph in a matrix form
- The dimension of the matrix A is n 3 b where n is the number of nodes and b is number of branches

- For a graph having n nodes and b branches, the complete incidence matrix A is a rectangular matrix of order n 3 b

In the matrix A with n rows and b columns, an entry aij in the i th row and j th column has the following values.

- aij = 1, if the j th branch is incident to and oriented away from the i th node
- aij = -1, if the j th branch incident to and oriented towards the i th node
- aij = 0, if the j th branch is not incident to the j th node



Directed Graph

Following the above convention, its incidence matrix A is given by

$$\begin{array}{c} \text{nodes} \\ \downarrow \end{array} \quad \begin{array}{c} \text{branches} \rightarrow \\ \begin{array}{cccccc} a & b & c & d & e & f \end{array} \end{array}$$

$$A = \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 1 \\ -1 & -1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & -1 \\ 0 & 0 & -1 & -1 & -1 & 0 \end{bmatrix}$$

- The entries in the first row indicate that three branches a, c, and f are incident tothe node 1 and they are oriented away from the node 1 and therefore the entries a11; a13 and a16 are 11.
- Other entries in the first row are zero as they are not connected to the node 1.
- We can complete the incidence matrix for the remaining nodes 2, 3, and 4.

PROPERTIES OF INCIDENCE MATRIX (A)

- Each column representing a branch contains two non-zero entries 11 and –1; the rest being zero. The unit entries in a column identify the nodes of the branch between which it is connected
- The unit entries in a row identify the branches incident at a node. Their number is called the degree of the node
- A degree of 1 for a row means that there is one branch incident at the node. This is commonly possible in a tree
- If the degree of a node is two, then it indicates that two branches are incident at the node and these are in series
- Columns of A with unit entries in two identical rows correspond to two branches with same end nodes and hence they are in parallel
- Given the incidence matrix A, the corresponding graph can be easily constructed since A is a complete mathematical replica of the graph
- If one row of A is deleted the resulting (n – 1) 3 b matrix is called the reduced incidence matrix A1. Given A1, A is easily obtained by using the first property

EXAMPLE 1:

Obtain the incidence matrix A from the following reduced incidence matrix A1 and draw its graph.

$$[A_1] = \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 0 & 0 & -1 & 1 \end{bmatrix}$$

Solution:

There are five rows and seven columns in the given reduced incidence matrix [A1]. Therefore, the number of rows in the complete incidence matrix A will be 5 1 1 5 6. There will be six nodes and seven branches in the graph. The dimensions of matrix A is 6 3 7. The last row in A, i.e. 6th row for the matrix A can be obtained by using the first property of the incidence matrix. It is seen that the first column of [A1] has a single non-zero element –1. Hence, the first element in the 6th row will be 11(–1 1 1 5 0). Second column of A1 has two non-zero elements 11 and –1, hence the second element in the 6th row will be 0. Proceeding in this manner we can obtain the 6th row.

The complete incidence matrix can therefore be written as

$$[A] = \begin{matrix} a \\ b \\ c \\ d \\ e \\ f \end{matrix} \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 0 & 0 & -1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

We have seen that any one of the rows of a complete incidence matrix can be obtained from the remaining rows. Thus, it is possible to delete any one row from A without losing any information in A1. Now the oriented graph can be constructed from the matrix A. The nodes

Video Content / Details of website for further learning (if any):

https://youtu.be/_5ejIMrMIOs

Important Books/Journals for further learning including the page nos.:

D P Kothari and I J Nagrath" Basic Electrical and Electronics Engineering" McGraw Hill 2014, Page no: 639,

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LECTURE HANDOUTS

L 29

ECE

II / III

Course Name with Code :**ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **MS.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK** **DATE OF LECTURE:**

Topic of Lecture: Tie Set And Cut Formulation

Introduction : **Tie-Set** Matrix and Loop Currents **Tie-Set** A **tie-set** is a **set** of branches contained in a loop such that each loop contains one link or chord and the remainder are tree branches. In graph theory, a cut is a partition of the vertices of a graph into two disjoint subsets. Any cut determines a cut-set, the set of edges that have one endpoint in each subset of the partition. These edges are said to cross the cut

Prerequisite knowledge for Complete understanding and learning of Topic:

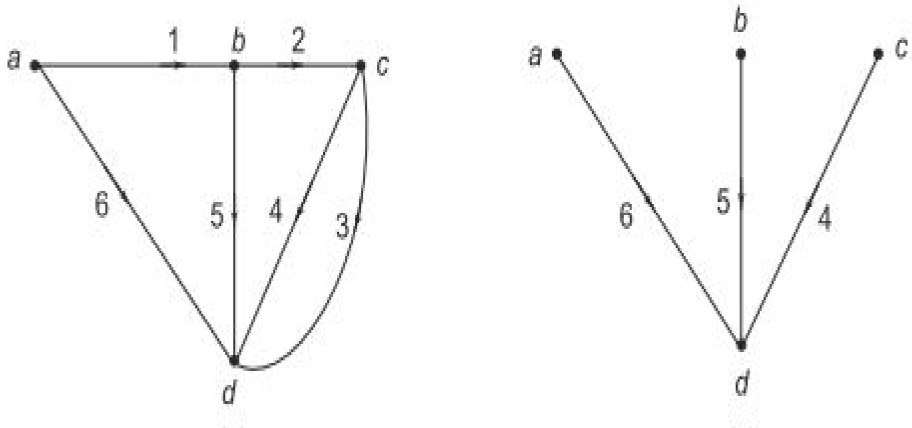
1. **Matrix of tie set**
2. **Matrix of cut set**

Detailed content of the Lecture:

Tie Set and Formulation:

The fundamental loop formed by one link has a unique path in the tree joining the two nodes of the link. This loop is also called f-loop or a tie-set.

(a). It has four nodes and six branches. One of its trees is arbitrarily chosen (b). The twigs of this tree are branches 4, 5, and 6. The links corresponding to this tree are branches 1, 2, and 3. Every link defines a fundamental loop of the network.



(a) (b)

Number of nodes n 5 4

Number of branches b 5 6
Number of tree branches or twigs 5 n – 1 5 3
Number of link branches I 5 b – (n – 1) 5 3

Video Content / Details of website for further learning (if any):

https://youtu.be/QgOAWBPx-4g

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no: 640

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LECTURE HANDOUTS

L 30

ECE

II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK**

DATE OF LECTURE:

Topic of Lecture: Two Port Network-One Port Network

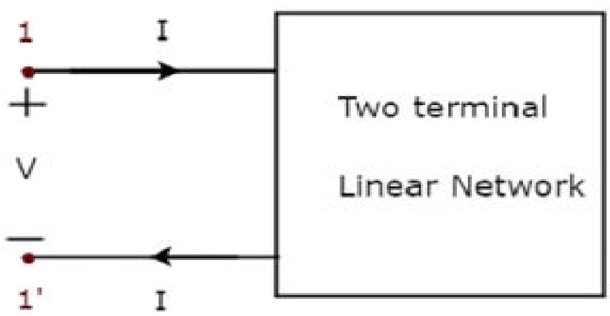
Introduction : **One port network** is a **two** terminal electrical **network** in which, current enters through **one** terminal and leaves through another terminal.Similarly, **two port network** is a pair of **two** terminal electrical **network** in which, current enters through **one** terminal and leaves through another terminal of each **port**

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **One port network**
2. **Two port network**

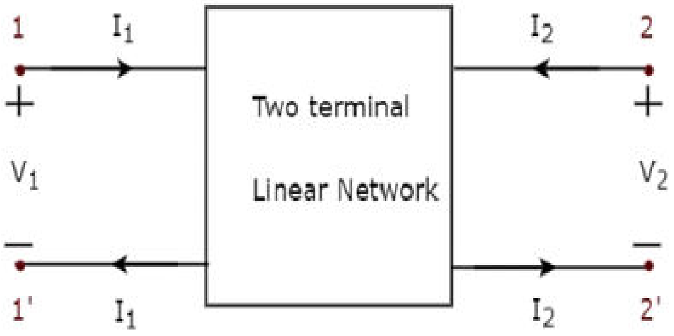
Detailed content of the Lecture:

- **One port network** is a two terminal electrical network in which, current enters through one terminal and leaves through another terminal.
- Resistors, inductors and capacitors are the examples of one port network because each one has two terminals



- Here, the pair of terminals, 1 & 1′ represents a port. In this case, we are having only one port since it is a one port network
- **Two port network** is a pair of two terminal electrical network in which, current enters through one terminal and leaves through another terminal of each port.

- As two terminal pairs acting as access points. The current entering one terminal of a pair leaves the other terminal in the pair. Three-terminal devices such as transistors can be configured into two-port networks.



- one pair of terminals, 1 & 1′ represents one port, which is called as **port1** and the other pair of terminals, 2 & 2′ represents another port, which is called as **port2**.

- Our study of two-port networks is for at least two reasons.
- First, such networks are useful in communications, control systems, power systems, and electronics.
- For example, they are used in electronics to model transistors and to facilitate cascaded design. Second, knowing the parameters of a two-port network enables us to treat it as a "black box" when embedded within a larger network

Video Content / Details of website for further learning (if any):
https://youtu.be/pn777Ya0OHk

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no: 687

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LECTURE HANDOUTS

L 31

ECE

II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK** **DATE OF LECTURE:**

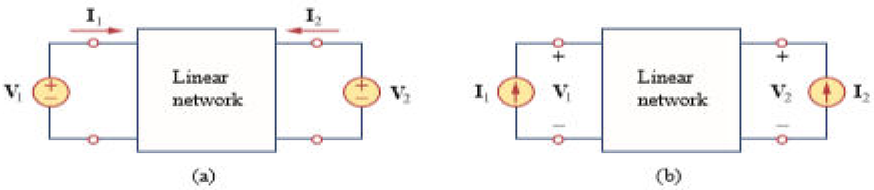
Topic of Lecture: Impedance Parameter, Admittance Parameter.

Introduction : Impedance and admittance parameters are commonly used in the synthesis of filters. They are also useful in the design and analysis of impedance-matching networks and power distribution networks. We discuss impedance parameters in this section and admittance parameters in the next section.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Linear Two-Port Network**
2. **Terminal Voltage**

Detailed content of the Lecture:



The linear two-port network: (a) driven by voltage sources, (b) driven by current sources.

A two-port network may be voltage-driven

$$\mathbf{V}_1 = \mathbf{z}_{11}\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2$$
$$\mathbf{V}_2 = \mathbf{z}_{21}\mathbf{I}_1 + \mathbf{z}_{22}\mathbf{I}_2$$

Matrix form

$$\begin{bmatrix}\mathbf{V}_1\\ \mathbf{V}_2\end{bmatrix} = \begin{bmatrix}\mathbf{z}_{11} & \mathbf{z}_{12}\\ \mathbf{z}_{21} & \mathbf{z}_{22}\end{bmatrix}\begin{bmatrix}\mathbf{I}_1\\ \mathbf{I}_2\end{bmatrix} = [\mathbf{z}]\begin{bmatrix}\mathbf{I}_1\\ \mathbf{I}_2\end{bmatrix}$$

$$\mathbf{z}_{11} = \left.\frac{\mathbf{V}_1}{\mathbf{I}_1}\right|_{\mathbf{I}_2=0}, \qquad \mathbf{z}_{12} = \left.\frac{\mathbf{V}_1}{\mathbf{I}_2}\right|_{\mathbf{I}_1=0}$$

$$\mathbf{z}_{21} = \left.\frac{\mathbf{V}_2}{\mathbf{I}_1}\right|_{\mathbf{I}_2=0}, \qquad \mathbf{z}_{22} = \left.\frac{\mathbf{V}_2}{\mathbf{I}_2}\right|_{\mathbf{I}_1=0}$$

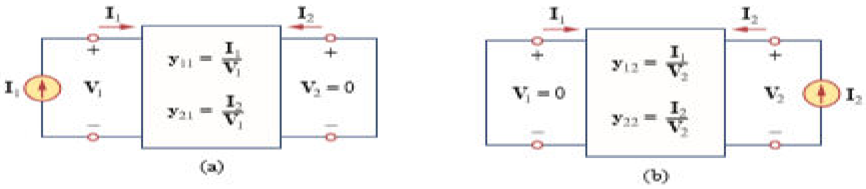
z_{11} = Open-circuit input impedance
z_{12} = Open-circuit transfer impedance from port 1 to port 2
z_{21} = Open-circuit transfer impedance from port 2 to port 1
z_{22} = Open-circuit output impedance

$$z_{11} = \frac{V_1}{I_1}, \qquad z_{21} = \frac{V_2}{I_1}$$

$$z_{12} = \frac{V_1}{I_2}, \qquad z_{22} = \frac{V_2}{I_2}$$

- The above procedure provides us with a means of calculating or measuring the z parameters.

Admittance Parameter.



Determination of the y parameters: (a) finding y_{11} and y_{21}, (b) finding y_{12} and y_{22}.

Terminal Voltages is

$$I_1 = y_{11}V_1 + y_{12}V_2$$
$$I_2 = y_{21}V_1 + y_{22}V_2$$

Matric form is

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = [y] \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0}, \qquad y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0}$$
$$y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0}, \qquad y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0}$$

y_{11} = Short-circuit input admittance
y_{12} = Short-circuit transfer admittance from port 2 to port 1
y_{21} = Short-circuit transfer admittance from port 1 to port 2
y_{22} = Short-circuit output admittance

finding and V1, and V2 then calculating

$$y_{11} = \frac{I_1}{V_1}, \qquad y_{21} = \frac{I_2}{V_1}$$
$$y_{12} = \frac{I_1}{V_2}, \qquad y_{22} = \frac{I_2}{V_2}$$

This procedure provides us with a means of calculating or measuring the y parameters

Video Content / Details of website for further learning (if any):
https://youtu.be/rzmW9fMBcVo
https://youtu.be/jWbWWoCY5n8

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no: 708,692

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LECTURE HANDOUTS

L 32

ECE | **II / III**

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK** **DATE OF LECTURE:**

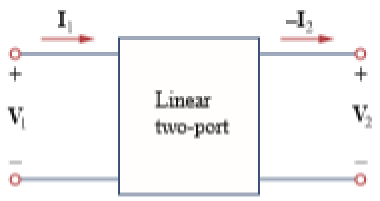
Topic of Lecture: Transmission line, Hybrid Parameter

Introduction : The **transmission line** has mainly four **parameters**, resistance, inductance, capacitance and shunt conductance. These **parameters** are uniformly distributed along the **line**. Emf produces in the **transmission line** resist the flow of current in the conductor, and this **parameter** is known as the inductance of the **line**. **Hybrid parameters** (also known as **h parameters**) are known as '**hybrid**' **parameters** as they use Z **parameters**, Y **parameters**, voltage ratio, and current ratios to represent the relationship between voltage and current in a two port network

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **EMF**
2. **Transmission Line**
3. **Terminal variable**

Detailed content of the Lecture:



Terminal variables used to define the ADCB parameters.

Parameters relates the variables at the input port to those at the output port.

$$V_1 = AV_2 - BI_2$$
$$I_1 = CV_2 - DI_2$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix} = [T] \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

The transmission parameters are determined as

$$\mathbf{A} = \frac{\mathbf{V}_1}{\mathbf{V}_2}\bigg|_{\mathbf{I}_2=0}, \quad \mathbf{B} = -\frac{\mathbf{V}_1}{\mathbf{I}_2}\bigg|_{\mathbf{V}_2=0}$$

$$\mathbf{C} = \frac{\mathbf{I}_1}{\mathbf{V}_2}\bigg|_{\mathbf{I}_2=0}, \quad \mathbf{D} = -\frac{\mathbf{I}_1}{\mathbf{I}_2}\bigg|_{\mathbf{V}_2=0}$$

Thus, the transmission parameters are called, specifically,

$\mathbf{A}$ = Open-circuit voltage ratio
$\mathbf{B}$ = Negative short-circuit transfer impedance
$\mathbf{C}$ = Open-circuit transfer admittance
$\mathbf{D}$ = Negative short-circuit current ratio

$$\mathbf{V}_2 = \mathbf{a}\mathbf{V}_1 - \mathbf{b}\mathbf{I}_1$$
$$\mathbf{I}_2 = \mathbf{c}\mathbf{V}_1 - \mathbf{d}\mathbf{I}_1$$

$$\begin{bmatrix} \mathbf{V}_2 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{a} & \mathbf{b} \\ \mathbf{c} & \mathbf{d} \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ -\mathbf{I}_1 \end{bmatrix} = [\mathbf{t}] \begin{bmatrix} \mathbf{V}_1 \\ -\mathbf{I}_1 \end{bmatrix}$$

The parameters $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$, and $\mathbf{d}$ are called the *inverse transmission*, or *t*, *parameters*. They are determined as follows:

$$\mathbf{a} = \frac{\mathbf{V}_2}{\mathbf{V}_1}\bigg|_{\mathbf{I}_1=0}, \quad \mathbf{b} = -\frac{\mathbf{V}_2}{\mathbf{I}_1}\bigg|_{\mathbf{V}_1=0}$$

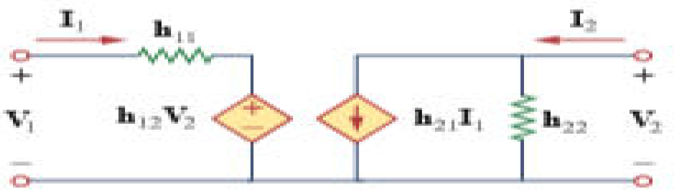
$$\mathbf{c} = \frac{\mathbf{I}_2}{\mathbf{V}_1}\bigg|_{\mathbf{I}_1=0}, \quad \mathbf{d} = -\frac{\mathbf{I}_2}{\mathbf{I}_1}\bigg|_{\mathbf{V}_1=0}$$

$\mathbf{a}$ = Open-circuit voltage gain
$\mathbf{b}$ = Negative short-circuit transfer impedance
$\mathbf{c}$ = Open-circuit transfer admittance
$\mathbf{d}$ = Negative short-circuit current gain

In terms of the transmission or inverse transmission parameters, a network is reciprocal if

$$\mathbf{AD} - \mathbf{BC} = 1, \quad \mathbf{ad} - \mathbf{bc} = 1$$

HYBRID PARAMETER:



The *h*-parameter equivalent network of a two-port network.

V1 and I2 impedance variable

$$\mathbf{V}_1 = \mathbf{h}_{11}\mathbf{I}_1 + \mathbf{h}_{12}\mathbf{V}_2$$
$$\mathbf{I}_2 = \mathbf{h}_{21}\mathbf{I}_1 + \mathbf{h}_{22}\mathbf{V}_2$$

Matrix form as

$$\begin{bmatrix} \mathbf{V}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{h}_{11} & \mathbf{h}_{12} \\ \mathbf{h}_{21} & \mathbf{h}_{22} \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{V}_2 \end{bmatrix} = [\mathbf{h}] \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{V}_2 \end{bmatrix}$$

The values of the parameters are determined as

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}, \quad h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}, \quad h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

h_{11} = Short-circuit input impedance

h_{12} = Open-circuit reverse voltage gain

h_{21} = Short-circuit forward current gain

h_{22} = Open-circuit output admittance

A set of parameters closely related to the h parameters are the g parameters or inverse hybrid parameters.

$$I_1 = g_{11}V_1 + g_{12}I_2$$
$$V_2 = g_{21}V_1 + g_{22}I_2$$

The values of the g parameters are determined as

$$g_{11} = \left.\frac{I_1}{V_1}\right|_{I_2=0}, \quad g_{12} = \left.\frac{I_1}{I_2}\right|_{V_1=0}$$

$$g_{21} = \left.\frac{V_2}{V_1}\right|_{I_2=0}, \quad g_{22} = \left.\frac{V_2}{I_2}\right|_{V_1=0}$$

g_{11} = Open-circuit input admittance

g_{12} = Short-circuit reverse current gain

g_{21} = Open-circuit forward voltage gain

g_{22} = Short-circuit output impedance

Video Content / Details of website for further learning (if any):

https://youtu.be/bRXQfZMzVJY
https://youtu.be/lr1jgbR5ca8

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no:716,713

Course Faculty

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LECTURE HANDOUTS

L 33

ECE

II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK** **DATE OF LECTURE:**

Topic of Lecture: Their inter- relationship

Introduction : Since the six sets of parameters relate the same input and output terminal variables of the same two-port network, they should be interrelated. If two sets of parameters exist, we can relate one set to the other set.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Parameters**
2. **Two port network**

Detailed content of the Lecture:

Since the six sets of parameters relate the same input and output terminal variables of the same two-port network, they should be interrelated. If two sets of parameters exist, we can relate one set to the other set.

Given the z parameters, let us obtain the y parameters

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = [z] \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \qquad (19.31)$$

or

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = [z]^{-1} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \qquad (19.32)$$

Also, from Eq. (19.9),

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = [y] \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \qquad (19.33)$$

Comparing Eqs. (19.32) and (19.33), we see that

$$[y] = [z]^{-1} \qquad (19.34)$$

The adjoint of the [z] matrix is

$$\begin{bmatrix} z_{22} & -z_{12} \\ -z_{21} & z_{11} \end{bmatrix}$$

and its determinant is

$$\Delta_z = z_{11}z_{22} - z_{12}z_{21}$$

Substituting these into Eq. (19.34), we get

$$\begin{bmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} \\ \mathbf{y}_{21} & \mathbf{y}_{22} \end{bmatrix} = \frac{\begin{bmatrix} \mathbf{z}_{22} & -\mathbf{z}_{12} \\ -\mathbf{z}_{21} & \mathbf{z}_{11} \end{bmatrix}}{\Delta_z} \tag{19.35}$$

Equating terms yields

$$\mathbf{y}_{11} = \frac{\mathbf{z}_{22}}{\Delta_z}, \qquad \mathbf{y}_{12} = -\frac{\mathbf{z}_{12}}{\Delta_z}, \qquad \mathbf{y}_{21} = -\frac{\mathbf{z}_{21}}{\Delta_z}, \qquad \mathbf{y}_{22} = \frac{\mathbf{z}_{11}}{\Delta_z} \tag{19.36}$$

As a second example, let us determine the h parameters from the z parameters. From Eq. (19.1),

$$\mathbf{V}_1 = \mathbf{z}_{11}\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2 \tag{19.37a}$$

$$\mathbf{V}_2 = \mathbf{z}_{21}\mathbf{I}_1 + \mathbf{z}_{22}\mathbf{I}_2 \tag{19.37b}$$

Making $\mathbf{I}_2$ the subject of Eq. (19.37b),

$$\mathbf{I}_2 = -\frac{\mathbf{z}_{21}}{\mathbf{z}_{22}}\mathbf{I}_1 + \frac{1}{\mathbf{z}_{22}}\mathbf{V}_2 \tag{19.38}$$

Substituting this into Eq. (19.37a),

$$\mathbf{V}_1 = \frac{\mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{22}}\mathbf{I}_1 + \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}}\mathbf{V}_2 \tag{19.39}$$

Putting Eqs. (19.38) and (19.39) in matrix form,

$$\begin{bmatrix} \mathbf{V}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} \frac{\Delta_z}{\mathbf{z}_{22}} & \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}} \\ -\frac{\mathbf{z}_{21}}{\mathbf{z}_{22}} & \frac{1}{\mathbf{z}_{22}} \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{V}_2 \end{bmatrix} \tag{19.40}$$

From Eq. (19.15),

$$\begin{bmatrix} \mathbf{V}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{h}_{11} & \mathbf{h}_{12} \\ \mathbf{h}_{21} & \mathbf{h}_{22} \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{V}_2 \end{bmatrix}$$

Comparing this with Eq. (19.40), we obtain

$$\mathbf{h}_{11} = \frac{\Delta_z}{\mathbf{z}_{22}}, \qquad \mathbf{h}_{12} = \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}}, \qquad \mathbf{h}_{21} = -\frac{\mathbf{z}_{21}}{\mathbf{z}_{22}}, \qquad \mathbf{h}_{22} = \frac{1}{\mathbf{z}_{22}} \tag{19.41}$$

Video Content / Details of website for further learning (if any):

https://youtu.be/rlWLP8MvpWQ

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no: 619

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LECTURE HANDOUTS

L 34

ECE

II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK**

DATE OF LECTURE:

Topic of Lecture: Resonant Frequency of circuits with L and C

Introduction : The most prominent feature of the frequency response of a circuit may be the sharp peak (or resonant peak) exhibited in its amplitude characteristic. The concept of resonance applies in several areas of science and engineering. Resonance occurs in any system that has a complex conjugate pair of poles; it is the cause of oscillations of stored energy from one form to another

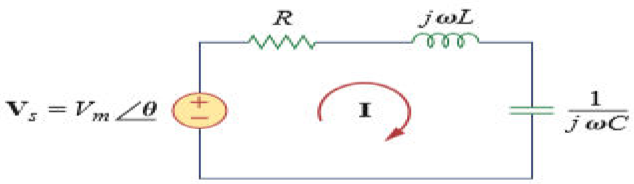
Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Resonance frequency**
2. **Series resonance**
3. **Parallel resonance**

Detailed content of the Lecture:

Resonance is a condition in an RLC circuit in which the capacitive and inductive reactances are equal in magnitude, thereby resulting in a purely resistive impedance.

Series Resonance



The series resonant circuit.

$$\mathbf{Z} = \mathbf{H}(\omega) = \frac{\mathbf{V}_s}{\mathbf{I}} = R + j\omega L + \frac{1}{j\omega C}$$

Or

$$\mathbf{Z} = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

Resonance results when the imaginary part of the transfer function is zero, or

$$\text{Im}(\mathbf{Z}) = \omega L - \frac{1}{\omega C} = 0$$

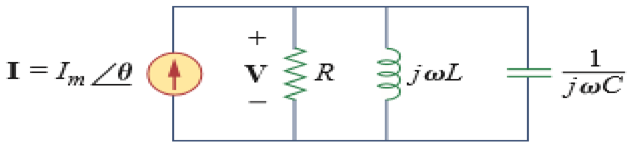
Since $\omega_0 = 2\pi f_0$,

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}$$

Note that at resonance:

1. The impedance is purely resistive, thus, In other words, the LC series combination acts like a short circuit, and the entire voltage is across R.
2. The voltage and the current are in phase, so that the power factor is unity.
3. The magnitude of the transfer function is minimum.
4. The inductor voltage and capacitor voltage can be much more than the source voltage

Parallel Resonance



The parallel resonant circuit.

$$\mathbf{Y} = H(\omega) = \frac{\mathbf{I}}{\mathbf{V}} = \frac{1}{R} + j\omega C + \frac{1}{j\omega L}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \text{ rad/s}$$

Video Content / Details of website for further learning (if any):

https://youtu.be/r72f0ZZusT0

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no: 691 to 627

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LECTURE HANDOUTS

L 35

ECE

II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK**

DATE OF LECTURE:

Topic of Lecture: Quality Factor and Bandwidth

Introduction : If the series RLC circuit is driven by a variable frequency at a constant voltage, then the magnitude of the current, I is proportional to the impedance, Z, therefore at resonance the power absorbed by the circuit must be at its maximum value as $P = I^2Z$

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Q factor**
2. **Resonance**
3. **Half power frequency**

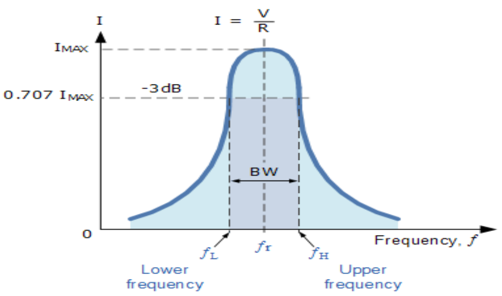
Detailed content of the Lecture:

Serial Resonance

Q –Factor

The quality factor relates the maximum or peak energy stored in the circuit (the reactance) to the energy dissipated (the resistance) during each cycle of oscillation meaning that it is a ratio of resonant frequency to bandwidth and the higher the circuit Q, the smaller the bandwidth, $Q = f_r / BW$.

Bandwidth



$$BW = \frac{f_r}{Q}, \quad f_H - f_L, \quad \frac{R}{L}\ \text{(rads)} \quad \text{or} \quad \frac{R}{2\pi L}\ \text{(Hz)}$$

Parallel Resonance
Q –Factor

$$\text{Quality Factor, } Q = \frac{R}{2\pi f L} = 2\pi f CR = R\sqrt{\frac{C}{L}}$$

Bandwidth

$$BW = f_r / Q \text{ or } BW = f_{upper} - f_{lower}$$

Video Content / Details of website for further learning (if any):

https://youtu.be/r72f0ZZusT0

Important Books/Journals for further learning including the page nos.:
W.H.Hayt, J.E.Kimmerly, and S.M.Durbin" Engineering circuit analysis" McGraw Hill, Page no: 619 to 633

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L 36

ECE

II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.SHENBAGADEVI,AP/ECE**

Unit : **IV – NETWORK TOPOLOGY AND TWO PORT NETWORK**

DATE OF LECTURE:

Topic of Lecture: Frequency and Magnitude scaling.

Introduction: There are two ways of scaling a circuit: magnitude or impedance scaling, and frequency scaling. While magnitude scaling leaves the frequency response of a circuit unaltered, frequency scaling shifts the frequency response up or down the frequency spectrum

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Resonance**
2. **Serial and parallel frequency**

Detailed content of the Lecture:

Serial resonance

Magnitude scaling is the process of increasing all impedance in a network by a factor, such that the frequency response remaining unchanged • Multiply impedances of each circuit elements by a constant km

Before scaling, $Z_R = R, Z_L = j\omega L, Z_C = 1/j\omega C$

After scaling the impedances

$$Z_R' = \text{km}\, Z_R,\ Z_L' = \text{km}\, Z_L,\ Z_C' = \text{km}\, Z_C$$

Parallel resonance

Before scaling, $Z_R = R, Z_L = j\omega L, Z_C = 1/j\omega C$

After frequency scaling, $Z_L = j\,(\omega k_f)L',\ Z_C = 1/j\,(\omega k_f)C'$

Scaled component values $R' = R, L' = L/k_f, C' = C/k_f$

Video Content / Details of website for further learning (if any): https://youtu.be/r72f0ZZusT0
Important Books/Journals for further learning including the page nos.: W.H.Hayt, J.E.Kimmerly, and S.M.Durbin” Engineering circuit analysis” McGraw Hill, Page no: 619 to 633

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Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty :Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Introduction to Transformers

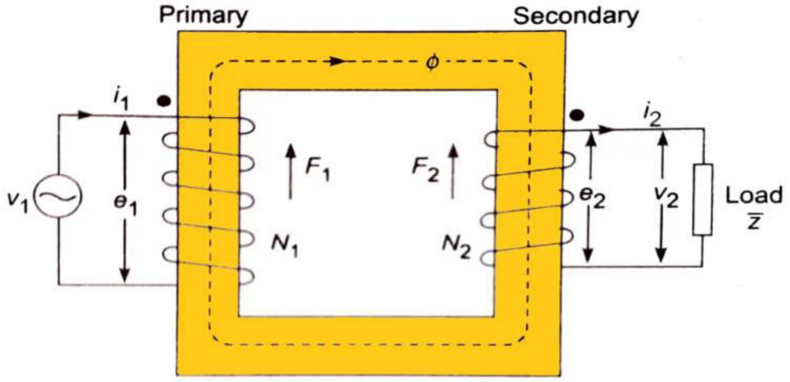
Introduction : The transformer is probably one of the most useful electrical devices ever invented. It Can change the magnitude of alternating voltage or current from one value to another. This useful Property of transformer is mainly responsible for the widespread use of alternating currents rather Than direct currents i.e. electric power is generated, transmitted and distributed in the form of Alternating current. Transformers have no moving parts, rugged and durable in constructions, thus requiring very little attention. they also have a very high efficiency-as high as 99%.In this chapter, We shall study some of the basic properties of transformers.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Primary Winding**
2. **Secondary Winding**
3. **Step up-Transformer**
4. **Step down-Transformer**
5. **Transformer Types**

Detailed content of the Lecture:

Transformer: It is commonly used to increase or decrease the supply voltage without a change in the frequency of AC between circuits. The transformer works on basic principles of electromagnetic induction and mutual induction



Primary Winding(N1) : The winding connected to the AC source
Secondary Winding(N2): One connected to the load

- The alternating voltage v1 whose magnitude is to be changed is applied to the primary
- Depending upon the no.of turns of the primary (N1) and secondary (N2)
- An alternating e.m.f. E2 is inducted in the secondary
- If v2>v1, it is called a step up-transformer
- If v2<v1, it is called a step down-transformer

Working principle of transformer:

- Alternating voltage v1 is applied to the primary; an alternating flux Φ is set up in the core.
- Alternating flux links both the windings and induces e.m.f. s E1 and E2 in them according to Faraday's laws of electromagnetic induction.
- E.m.f. E1 is termed as primary e.m.f. and e.m.f. E2 is termed as secondary e.m.f.

$$E1 = -N1\, d\Phi/dt$$

$$E2 = -N2\, d\Phi/dt$$

$$E2/E1 = N2/N1$$

- If N2>N1 ,then E2>E1 = we get step up-transformer
- If N2<N1 ,then E2<E1 = we get step down-transformer

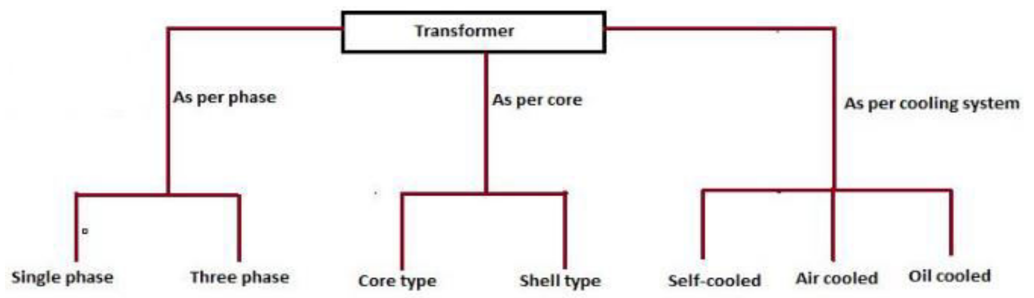
The following points may be noted carefully :

- The transformer action is based on the laws of electromagnetic induction
- There is no electrical connection between the primary and secondary. The a.c power is transferred from primary to secondary through magnetic flux.
- The is no change in frequency

The losses that occur in transformer are:

(a) Core losses – eddy current and hysteresis losses
(b) Copper losses – in the resistance of the windings

TYPES OF TRANSFORMER:



Video Content / Details of website for further learning (if any):

https://youtu.be/U2vji08cfns

Important Books/Journals for further learning including the page nos.:
I.J.Nagrath "Basic Electrical and Electronics Engineering"McGraw Hill 2014Page no:378

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LECTURE HANDOUTS

L 38

ECE

II / III

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Ideal Transformer

Introduction : It is an imaginary **transformer** that has no core loss, no ohmic resistance, and no leakage flux. The **ideal transformer** has the following important characteristic. The resistance of their primary and secondary winding becomes zero. The core of the **ideal transformer** has infinite permeability

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Winding resistance**
2. **Leakage Flux**
3. **Iron losses**

Detailed content of the Lecture:

IDEAL TRANSFORMER

An ideal transformer is one that has

- No winding resistance
- No leakage flux i.e. the same flux links both the windings
- No iron losses(i.e. eddy current and hysteresis losses) in the core

The ideal transformer has no loses that is there is no magnetic leakage and ohmic resistance in its windings. There won't be any core losses or I^2R.

Characteristics Of Ideal Transformer

Zero winding resistance:

- It is assumed that, resistance of primary as well as secondary winding of an ideal transformer is zero. That is, both the coils are purely inductive in nature.

Infinite permeability of the core:

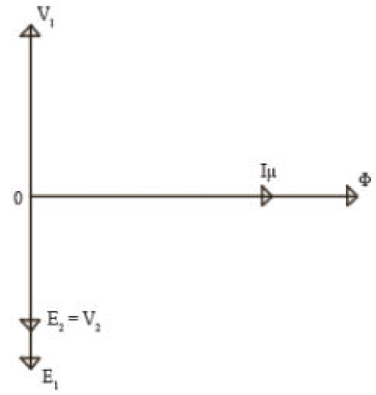
- Higher the permeability, lesser the mmf required for flux establishment. That means, if permeability is high, less magnetizing current is required to magnetize the transformer core.

No leakage flux:

- Leakage flux is a part of magnetic flux which does not get linked with secondary winding. In an ideal transformer, it is assumed that entire amount of flux get linked with secondary winding (that is, no leakage flux).

100% efficiency:

- An ideal transformer does not have any losses like hysteresis loss, eddy current loss etc. So, the output power of an ideal transformer is exactly equal to the input power. Hence, 100% efficiency.



- If an alternating voltage V_1 is applied to the primary winding of an ideal transformer, counter emf E_1 will be induced in the primary winding.
- As windings are purely inductive, this induced emf E_1 will be exactly equal to the apply voltage but in 180 degree phase opposition. Current drawn from the source produces required magnetic flux.
- Due to primary winding being purely inductive, this current lags 90° behind induced emf E_1. This current is called magnetizing current of the transformer I_μ. This magnetizing current I_μ produces alternating magnetic flux Φ. This flux Φ gets linked with the secondary winding and emf E_2 gets induced by mutual induction.
- This mutually induced emf E_2 is in phase with E_2. If closed circuit is provided at secondary winding, E_2 causes current I_2 to flow in the circuit.
- For an ideal transformer, $E_1I_1 = E_2I_2$

Video Content / Details of website for further learning (if any):

https://youtu.be/2U5MYBHUkSw

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LECTURE HANDOUTS

L 39

ECE

II / III

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Construction and operational features of DC machines

Introduction : we will have a look at Introduction to DC Machines. Like alternating current machines, there are 2 types of DC machines first one is DC motors that convert electrical power into mechanical power and the second one is DC generator that converts mechanical power into electrical.

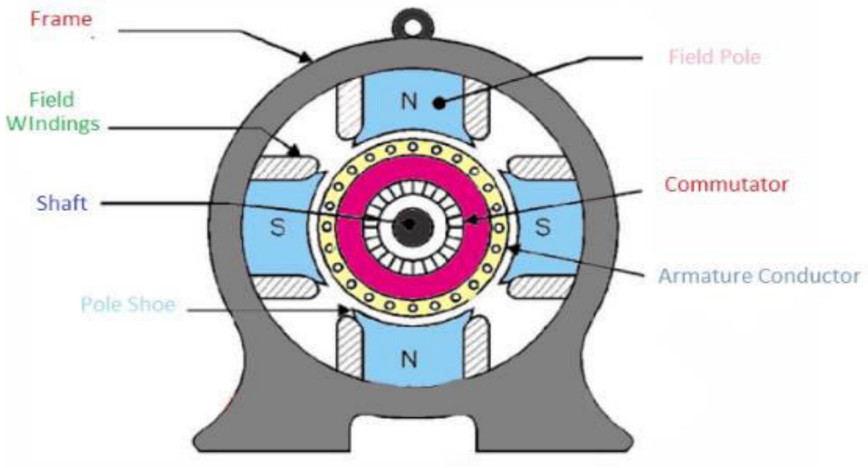
Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Core**
2. **Windings**
3. **Insulating Agents**

Detailed content of the Lecture:

- DC Machines are types of electrical machines that use dc current in the case of dc motors and generates dc voltages in case of dc generator.
- DC motor transforms electrical power into mechanical power and the generator converts mechanical power into electrical.
- As in power, generation system, and industries mostly ac machines like an induction motor, synchronous motor, generators are employed but the use of dc machines cannot be denied due to its constant speed providing the capability.
- The physical construction and designing of both dc motors and generators are alike to each other. The dc generator is used in some safe environment where is no need of special protection and circuitry for the generator.
- While the motor is employed in such an environment where it can be easily affected by environmental conditions like moisture, dust, so it needs a special structure that can provide resistant to dust, fire, and some other related effects.
- As we are familiar with the common use of dc battery that used only for some limited applications where less amount of energy is required but such applications where a large amount of dc power is needed dc machines is the best replacement of the battery

DC MACHINES CONSTRUCTION:



Yoke

- yoke of machines is also known as the frame, the main working of this part is to provide protection to the internal circuitry of a machine from the outer environment, temperature, moisture, and some other factors
- This part of the machine is constructed with the cast steel and cast iron

Pole Core

- At stator of the dc machines, the poles are of an electromagnet the windings on these poles are known as the field windings.
- The input provided at the stator connected with the field windings generate flux at the stator and make poles electromagnet.
- These poles are constructed with cast steel, cast iron

Field Windings

- Windings are wound at the sating part of machines on the poles at the stator. These windings are constructed with copper.
- Current provided at these windings generates flux and makes poles electromagnet.

Armature Core

- Core of armature consists of a large no of slots and armature windings are located in these slots.
- It has less reluctance path for the interaction of stator flux with the armature windings, this core is constructed with the less reluctance material like cast iron
- And there are laminations of different substance is used to reduce the eddy current losses

Armature Windings

- Indings wound on the rotor if the dc machine is known as the armature windings. When the rotor rotates due to flux linking of stator the voltage induced in this part of machines.
- Constructed with copper like the stator windings.

Commutator

- Commutator is slip rings mounted at the shaft of the machines the main purpose of these commutators is to transmit current from the armature windings to the load.
- Commutators also convert ac power generated by the machine into the dc power, we will discuss this phenomenon how ac converts into dc by these commutators in coming tutorials.

Carbon Brushes

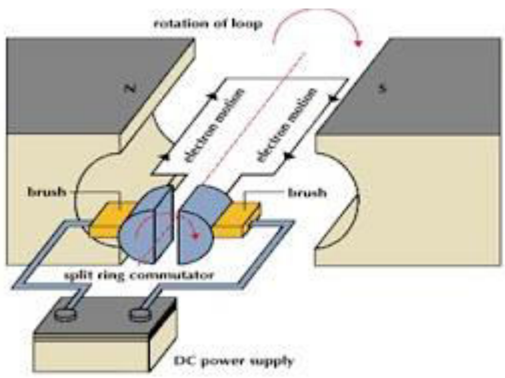
- Brushes are connected with the commutators and get current from the commutator and provides to the load.
- Constructed with the carbon and their main function is to reduce the sparking at load and machine connection points.

Working Principle of DC Machines

- Any types of electrical machine either AC or DC works on the phenomena of Faraday's law of electromagnetic induction.

- This law states that if any conductor through which current is passing is placed in the magnetic field a force act on this conductor due that it rotates in the field.
- The direction of rotation of this conductor in the field can be found by using the very famous Left Hand Rule of Fleming.
- The Faraday's law also states that if we put any conductive loop in the field the voltage will induce in that conductive device the direction of induced voltage can be fined by the right-hand rule.

EMF= dø/dt



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LECTURE HANDOUTS

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ECE

II / III

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: EMF and Torque Equation

Introduction : As ac machines are further divided into sub categories like an induction motor, induction generator, synchronous motor, synchronous generator, DC machines also have different types like shunt motor, shunt generator, series motor, series generator, etc. In DC machines like the ac machines alternating current and voltage produces that converts then to the DC current and voltage by a process called commutation.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Flux**
2. **EMF equation of DC Machines**
3. **Armature Torque**
4. **Shaft Torque**

Detailed content of the Lecture:

EMF EQUATION OF DC MOTOR

P = number of field poles
Ø = flux produced per pole in Wb (weber)
Z = total no. of armature conductors
A = no. of parallel paths in armature
N = rotational speed of armature in revolutions per min. (rpm)

Now,

- Average emf generated per conductor is given by $d\Phi/dt$ (Volts) ... eq. 1
- Flux cut by one conductor in one revolution = $d\Phi = P\Phi$ ….(Weber),
- Number of revolutions per second (speed in RPS) = N/60
- Therefore, time for one revolution = dt = 60/N (Seconds)
- From eq. 1, emf generated per conductor = $d\Phi/dt = P\Phi N/60$ (Volts)

$$E_g = P\Phi NZ / 60A$$

TORQUE EQUATION OF DC MOTOR

- $T = F \times r$ (N-m)
  where, F = force and r = radius of the armature
- Work done by this force in once revolution = Force × distance = $F \times 2\pi r$ (where, $2\pi r$ = circumference of the armature)
- Net power developed in the armature = word done / time = (force × circumference × no. of revolutions) / time = $(F \times 2\pi r \times N) / 60$ (J/S)

But, $F \times r = T$ and $2\pi N/60$ = angular velocity ω in r/s

Net power developed in the armature = $P = T \times \omega$ (J/S)

Armature Torque (Ta)

- The power developed in the armature can be given as, $Pa = Ta \times \omega = Ta \times 2\pi N/60$
- The mechanical power developed in the armature is converted from the electrical power, Therefore, mechanical power = electrical power
  That means, $Ta \times 2\pi N/60 = Eb.Ia$

$$Eb = P\Phi NZ / 60A$$

$$Ta \times 2\pi N/60 = (P\Phi NZ / 60A) \times Ia$$

$$\mathbf{Ta = (PZ / 2\pi A) \times \Phi.Ia} \text{ (N-m)}$$

$$Ta \propto \Phi.Ia$$

Shaft Torque (Tsh)

- Due to iron and friction losses in a dc machine, the total developed armature torque is not available at the shaft of the machine. Some torque is lost, and therefore, shaft torque is always less than the armature torque. Shaft torque of a DC motor is given as,
  Tsh = output in watts / $(2\pi N/60)$ ....(where, N is speed in RPM)

Video Content / Details of website for further learning (if any):

https://youtu.be/S8VIewhwqZs

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LECTURE HANDOUTS

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ECE

II / III

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Characteristics of DC motor

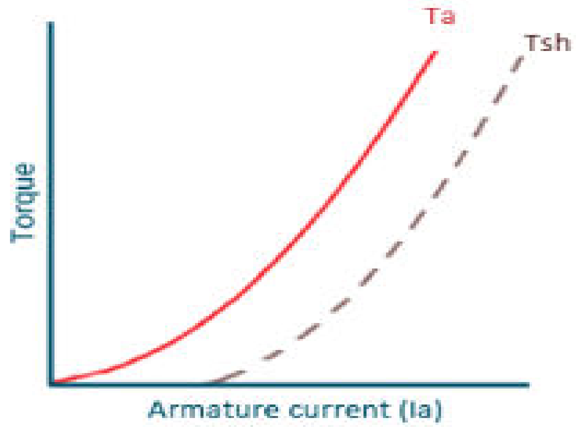
Introduction : The shaft torque (Tsh) is less than armature torque (Ta) due to stray losses. Hence, the **curve** Tsh vs Ia lies slightly lower. In **DC** series **motors**, (prior to magnetic saturation) torque increases as the square of armature current, these **motors** are used where high starting torque is required

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Torque Vs Armature Current
2. Speed Vs Armature Current
3. Speed Vs Torque

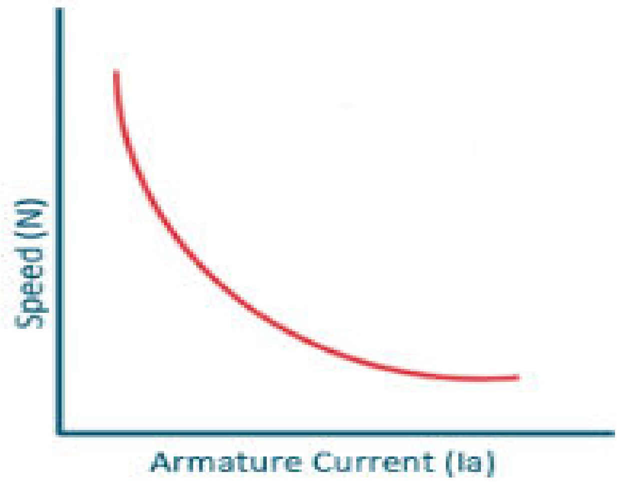
Detailed content of the Lecture:

Torque Vs Armature Current (T_a/I_a)



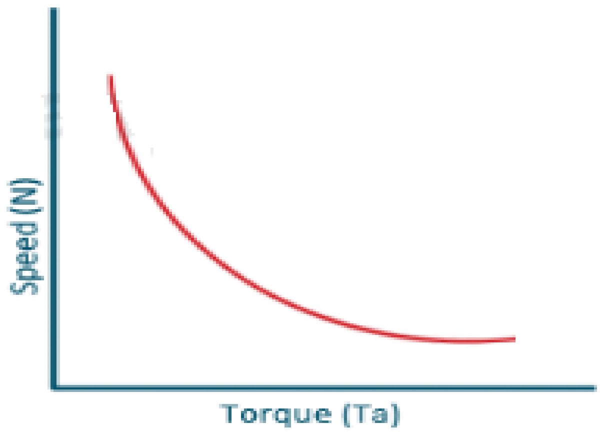
- it is the curve between armature torque T_a and armature current I_a of a d.c motor
- it is also known as electrical characteristics of the motor

Speed Vs Armature Current (N/Ia)



- It is the curve between speed N and armature current Ia of a d.c. motor.
- It is very important characteristics as it is often the deciding factor in the selection of the motor for a particular application

Speed Vs Torque (N/Ta)



- It is the curve between speed N and armature torque Ta of a dc motor.
- It also known as mechanical characteristics

Video Content / Details of website for further learning (if any):

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II / III

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Synchronous Machines, Construction

Introduction : An alternating voltage is generated in a single conductor or alternating coil rotating in a uniform magnetic field with stationary poles an alternating voltage will also be generated in stationary armature conductor when the field poles rotate past the conductors. thus , we see that as long as there is a relative motion between the armature conductors and field flux there will be a voltage generated in the armature conductors. in both cases the wave shape of voltage is a sine curve

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Magnetic flux**
2. **Stator Windings**
3. **Rotor Windings**

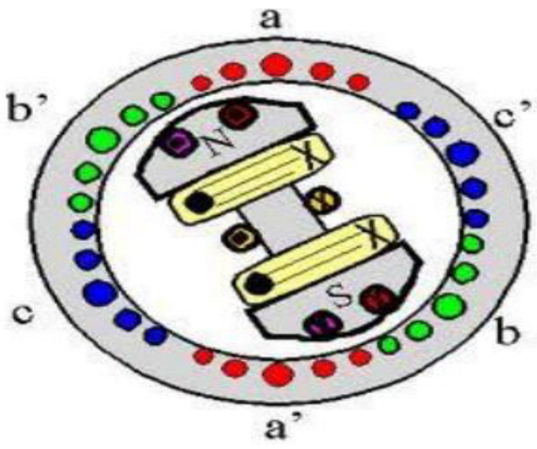
Detailed content of the Lecture:

Main features of synchronous machines:

- A synchronous machine is an ac machine whose speed under steady-state conditions is proportional to the frequency of the current in its armature.
- The rotor, along with the magnetic field created by the dc field current on the rotor, rotates at the same speed as, or in synchronism with, the rotating magnetic field produced by the armature currents, and a steady torque results.

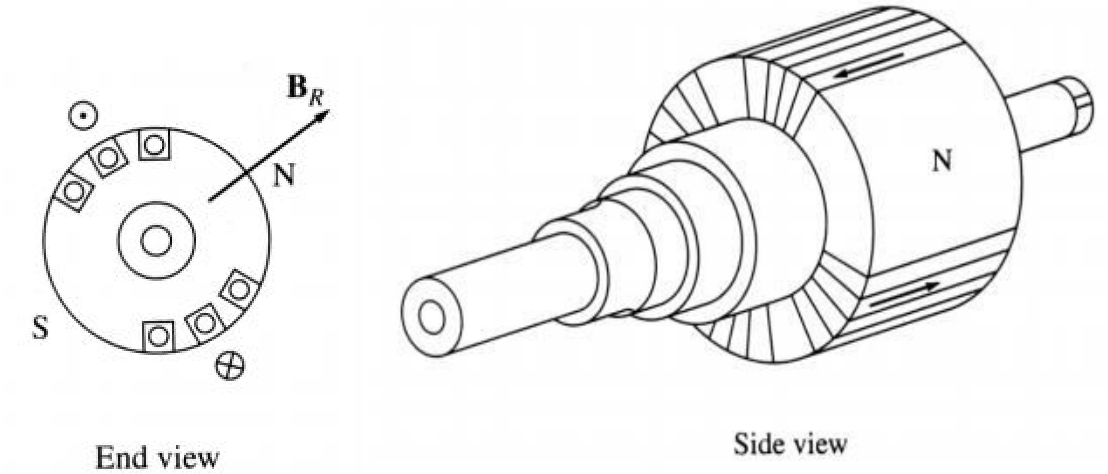
In a synchronous generator, a DC current is applied to the rotor winding producing a rotor magnetic field. The rotor is then turned by external means producing a rotating magnetic field, which induces a 3-phase voltage within the stator winding.

- Field windings are the windings producing the main magnetic field (rotor windings)
- Armature windings are the windings where the main voltage is induced (stator windings)



Construction of synchronous machines

The rotor of a synchronous machine is a large electromagnet. The magnetic poles can be either salient (sticking out of rotor surface) or nonsalient construction.



- Supply the DC power from an external DC source to the rotor by means of slip rings and brushes;
- Supply the DC power from a special DC power source mounted directly on the shaft of the machine.

Video Content / Details of website for further learning (if any):

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ECE | **II / III**

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Equation and Characteristics

Introduction : we see that as long as there is a relative motion between the armature conductors and field flux there will be a voltage generated in the armature conductors. in both cases the wave shape of voltage is a sine curve

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **EMF equation**
2. **Speed**
3. **Starting Torque**

Detailed content of the Lecture:

Synchronous machine is an AC machine whose satisfactory operation depends upon the maintenance of the following relationship

$$N_s = \frac{120f}{P} \ldots\ldots\ldots(1) \quad \text{or}$$

$$f = \frac{PN_s}{120}$$

Where,

N_s is the synchronous speed in revolution per minute (r.p.m)
f is the supply frequency
P is the number of poles of the machine.

CHARACTERISTICS

Some of the key characteristics of a synchronous motor which differentiates it from other motors are as follows:

Speed

Speed of ranges from 150 rpm to 1800 rpm. The speed is synchronous and does not depend on load conditions. Speed always remain constant from no load to full load

$$N = 120 \times \frac{f}{p}$$

Where,

N = Speed of Motor in rpm

f = frequency, and

p = No. of poles

Starting Torque

External force is required to start the synchronous motor as it has no starting torque.

Rating

The power rating of synchronous motors ranges between 150kW to 15MW.

Efficiency

The Synchronous Motors are highly efficient machines and their efficiency is much greater than induction motors.

Maintenance

The Synchronous motors use brushless Exciter which decreases the maintenance problem.

Power Factor Correction

These motors have high power factor correction, Hence they are used in areas where power factor correction is needed

Video Content / Details of website for further learning (if any):

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II / III

Course Name with Code : **ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01**

Course Faculty : **Ms.K.Shenbagadevi,AP/ECE**

Unit : **V – Electric Machines** **Date of Lecture:**

Topic of Lecture: Induction Motors: Construction.

Introduction : An electric motor converts electrical power to mechanical power in its rotor (rotating part). There are several ways to supply power to the rotor. In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Induction motors are widely used, especially polyphase induction motors, which are frequently used in industrial drives. Induction motors are now the preferred choice for industrial motors due to their rugged construction, absence of brushes (which are required in most DC motors) and the ability to control the speed of the motor.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Squirrel cage rotor**
2. **Wound rotor**

Detailed content of the Lecture:

An induction motor (IM) is a type of asynchronous AC motor where power is supplied to the rotating device by means of electromagnetic induction.

CONSTRUCTION

A typical motor consists of two parts namely stator and rotor like other type of motors.

- An outside stationary stator having coils supplied with AC current to produce a rotating magnetic field,
- An inside rotor attached to the output shaft that is given a torque by the rotating field.

STATOR CONSTRUCTION

The stator of an induction motor is laminated iron core with slots similar to a stator of a synchronous machine. Coils are placed in the slots to form a three or single phase winding.

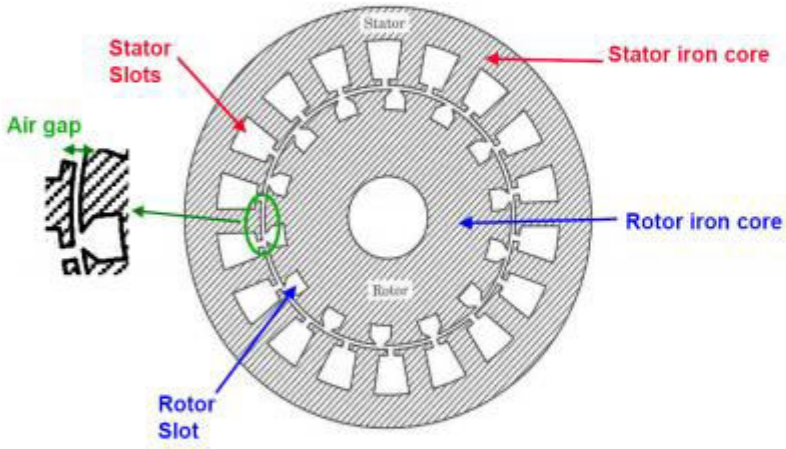
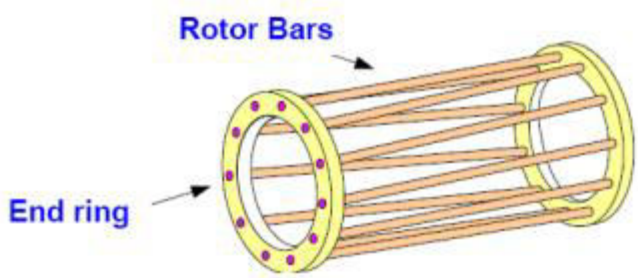


FIG: Induction motor magnetic circuit showing stator and rotor slots

Type of rotors

1.Squirrel cage rotor

- In the squirrel-cage rotor, the rotor winding consists of single copper or aluminium bars placed in the slots and short-circuited by end-rings on both sides of the rotor.
- Most of single phase induction motors have Squirrel-Cage rotor. One or 2 fans are attached to the shaft in the sides of rotor to cool the circuit.



2.Wound rotor

- It is usually for large 3 phase induction motors.
- Rotor has a winding the same as stator and the end of each phase is connected to a slip ring.
- Compared to squirrel cage rotors, wound rotor motors are expensive and require maintenance of the slip rings and brushes, so it is not so common in industry applications.

Video Content / Details of website for further learning (if any):
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ECE

IV / VII

Course Name with Code : ELECTRIC NERWORK ANALYSIS AND MACHINES & 19ECC01

Course Faculty : Ms.K.SHENBAGADEVI,AP/ECE

Unit : V – ELECTRIC MACHINES **Date of Lecture:**

Topic of Lecture: Applications

Introduction : An **induction motor** or asynchronous **motor** is an AC electric **motor** in which the electric current in the rotor needed to produce torque is obtained by electromagnetic **induction** from the magnetic field of the stator winding. An **induction motor** can therefore be made without electrical connections to the rotor

Prerequisite knowledge for Complete understanding and learning of Topic:

1. **Slip ring**
2. **Squirrel cage**

Detailed content of the Lecture:

Application Of Induction Motor

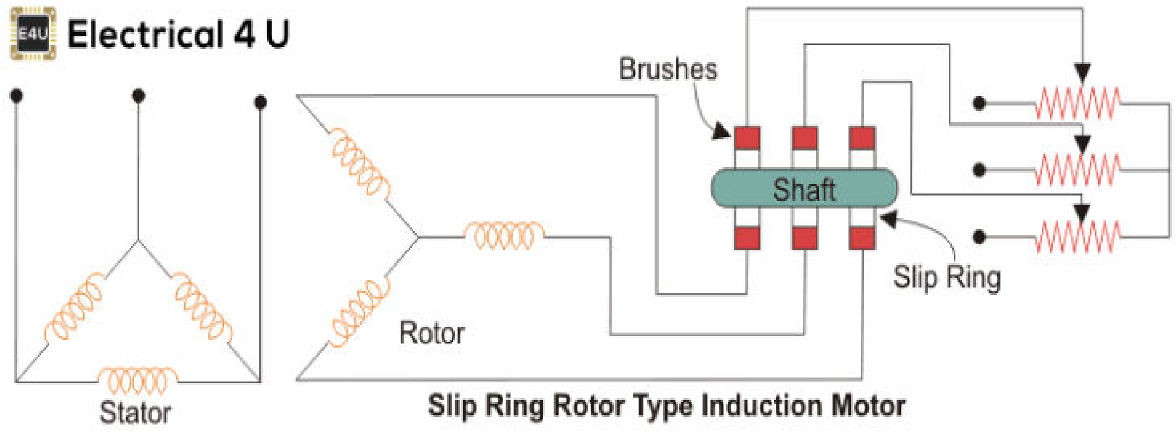
1. Squirrel Cage Rotor
2. Slip Ring Rotor or Wound Rotor Type

Squirrel Cage Rotor

A squirrel type rotor is used in a squirrel cage motor. It has a cylindrical laminated core with slot parallel to the shaft, uninsulated conductor bar of aluminum or copper in each slot of the rotor and the rotor conductor are short-circuited by heavy end ring at the end of the rotor.

Slip Ring Rotor consists of a sloted armature, insulated conductor arranged in slots forming a three-phase double layer distribution winding similar to that of the stator winding. The rotor is star connected and the open ends of the rotor are connected with brushes to slip ring mounted in the shaft whereas the other end of slip ring is connected to a variable resistor

Slip ring inductor motor have High Starting Torque and low starting current so the load which require this operational condition uses slip ring type rotor induction motor.
Ex :- Conveyors, Cranes, Compressors, Elevators, Hoist etc



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