

ECE3051 - Electrical Energy Systems Summary Notes

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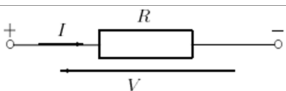
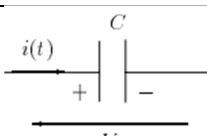
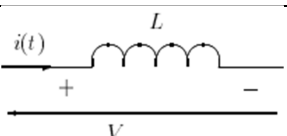
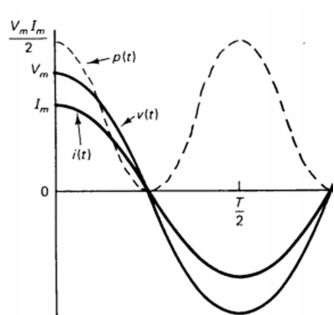
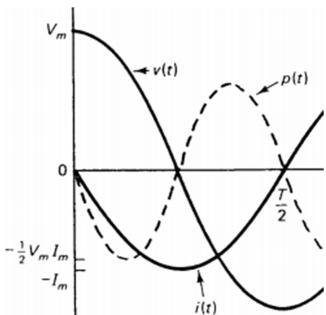
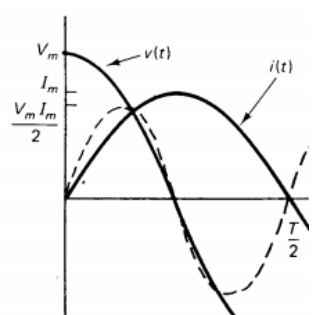
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AC Circuit Theory

Basic Circuit Elements

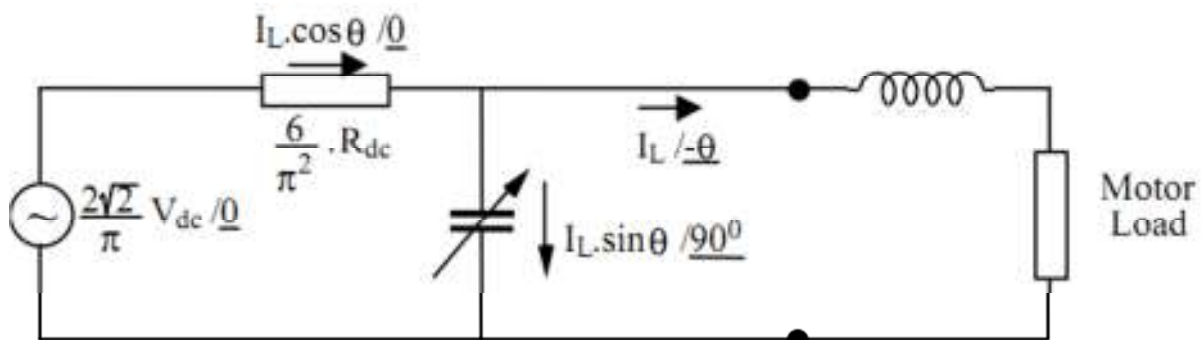
Name	Resistor	Capacitor	Inductor
Image			
Relation	Voltage and current related through Ohm's Law: $v(t) = i(t)R$ $v(t) = V_m \cos \omega t$ $i(t) = \frac{V_m}{R} \cos \omega t = I_m \cos \omega t$	Current through capacitor is proportional to rate of change of voltage. $i(t) = C \frac{dv}{dt}$ $v(t) = \frac{1}{C} \int i(t) dt$ For sinusoidal voltage: $i(t) = -(\omega C V_m) \sin \omega t$ $= \omega C V_m \cos(\omega t + 90^\circ)$	Voltage across terminals is proportional to the rate of change of current. $v(t) = L \frac{di(t)}{dt}$ For sinusoidal current: $v(t) = -\omega L I_m \sin \omega t$ $= \omega L I_m \cos(\omega t + 90^\circ)$
Power	Resistor dissipates power in form of heat. Instantaneous power: $p(t) = v(t)i(t) = \frac{V_m^2}{R} \cos^2 \omega t$ $p(t) = \frac{V_m^2}{2R} (1 + \cos 2\omega t)$ Average Power: $P = \frac{V_m^2}{2R} = \frac{1}{2} V_m I_m$	Instantaneous power: $p(t) = v(t)i(t)$ $= -(\omega C V_m^2) \cos \omega t \sin \omega t$ $= -\frac{1}{2} \omega C V_m^2 \sin 2\omega t$ Average power through capacitor is zero.	Instantaneous power: $p(t) = -\frac{1}{2} \omega L I_m^2 \sin 2\omega t$ Average power through an inductor is zero.
Phase	Voltage and current are in phase (0°) 	The current leads the voltage ($+90^\circ$) 	The current lags the voltage (-90°) 

Equivalent Circuit

By considering the power balance of the inverter:

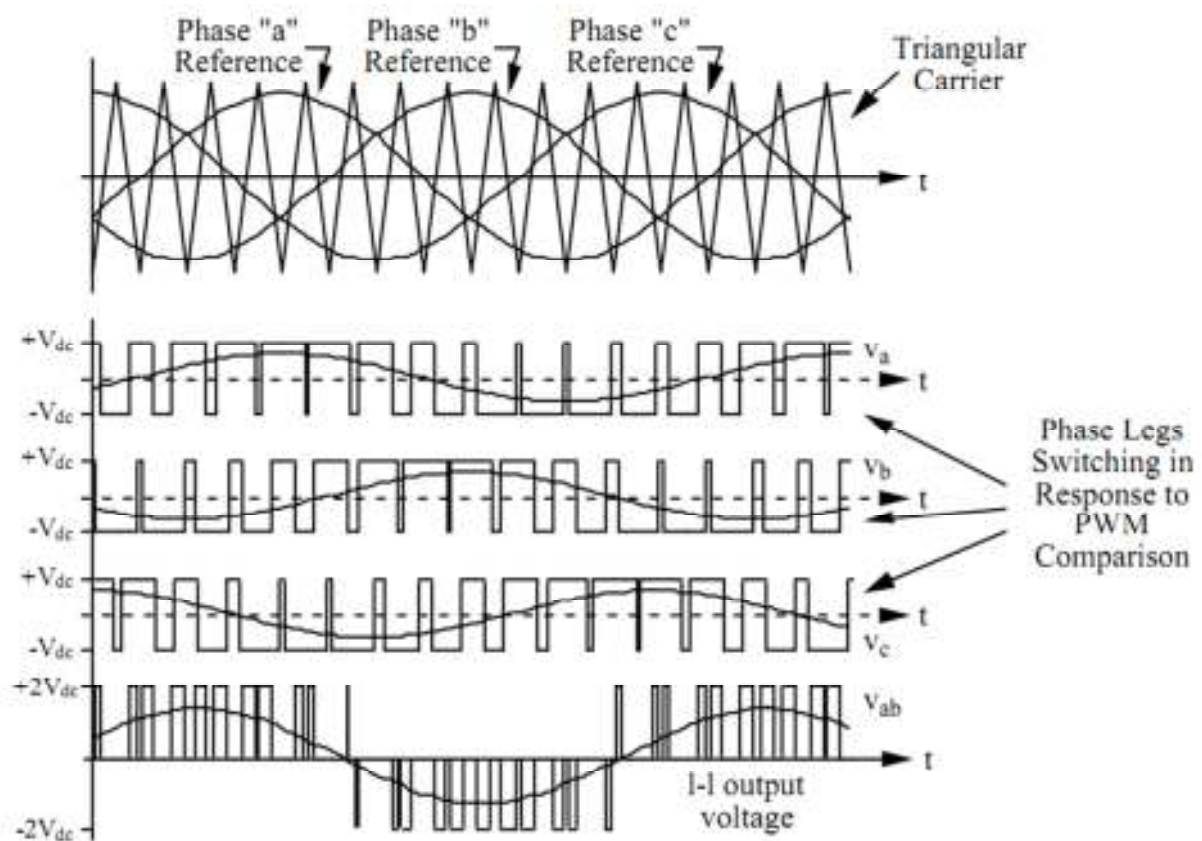
$$DC \text{ input} \rightarrow 2V_{DC}I_{DC} = 3V_{ph}I_L \cos \theta \leftarrow 3 \text{ phase output}$$

- Only the **real** component of the AC output current reflects back through to the DC side.
- The **reactive** component circulates through the inverter, which can therefore be modelled as variable capacitor.



Pulse Width Modulation

As with single phase inverter, problems of a six step modulation can be largely overcome by using a PWM strategy to create the AC output voltages of the inverter.



Results in a maximum output magnitude of $V_{LN} = V_{DC}/\sqrt{2}$

Synchronous Generators

Stator – has 3-phase windings distributed evenly (same as induction motor), connected to output terminals/load

Rotor – Has a single coil winding which is energised by a DC current to produce a **constant** magnetic field.

- DC current is supplied through slip rings
- Rotor is driven externally by e.g. turbine
- Rotating magnetic field is produced, induces current in surrounding 3-phase stator windings.

The induced electrical voltage will have angular frequency depending on the rotational speed of the rotor n (in rpm):

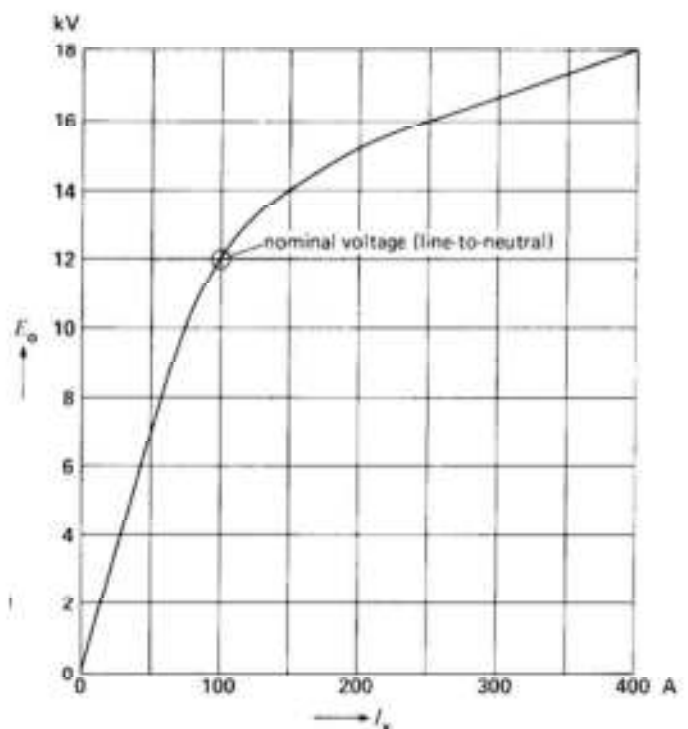
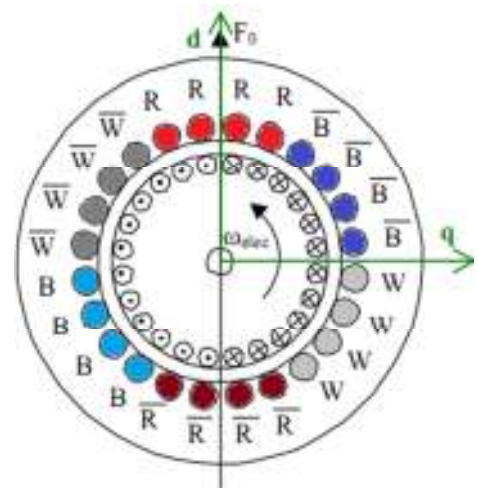
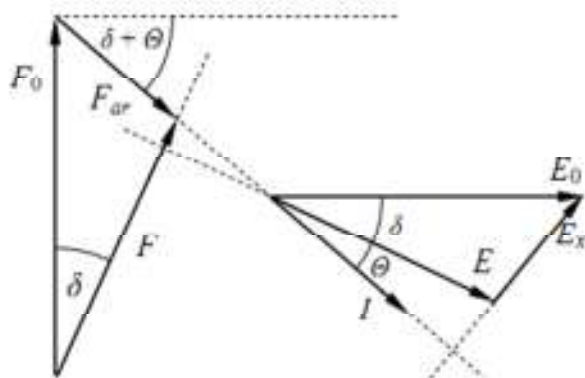
$$\omega_{elec} = \frac{p}{2} 2\pi \frac{n}{60}$$

$$E_0 = 4.44 \frac{p}{2} \frac{n}{60} N k_f \phi_m$$

and RMS magnitude which also depends on peak flux magnitude.

- Peak flux magnitude is a function of excitation current in the **rotor** winding
- Falls off because of flux saturation

The current in the **stator windings** will in turn produce an mmf F_{ar} which adds to the original **rotor** field winding mmf F_0 to produce a resultant rotating mmf F :



F_0 produces E_0 and F produces E .

- The resultant stator winding voltage = E
- This loss modelled by an equivalent **armature reactance**
- Armature reactance + leakage reactance = **synchronous reactance**

Θ = power factor angle of external load

δ = torque angle