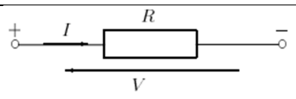
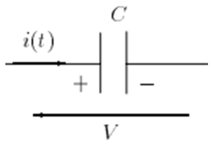
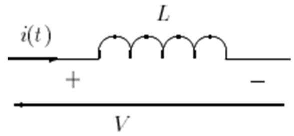
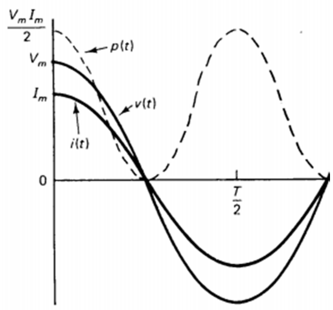
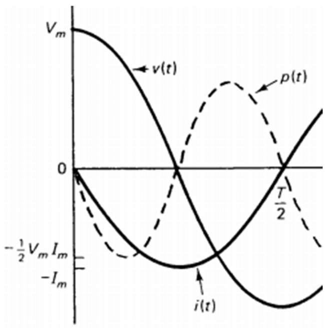
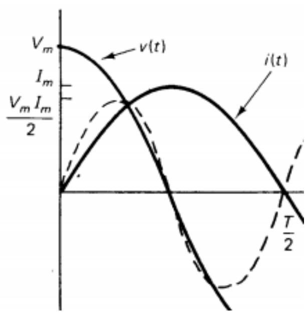
ECE3051 - Electrical Energy Systems Summary Notes

Contents

AC Circuit Theory

Basic Circuit Elements

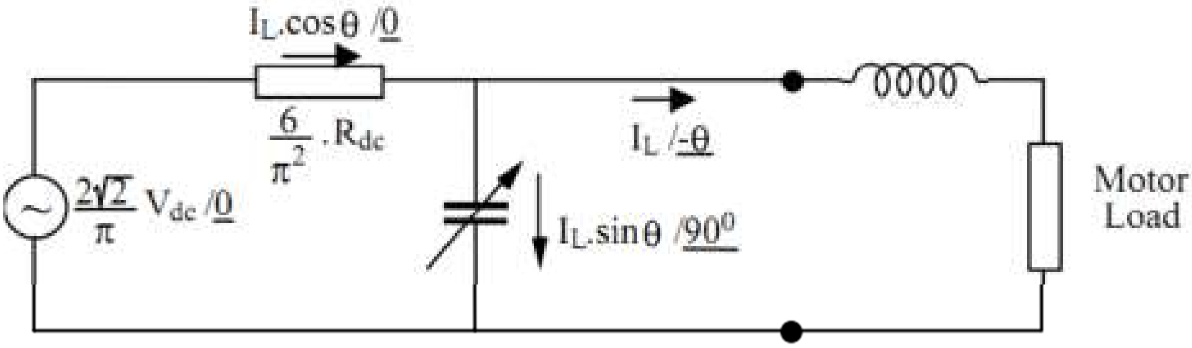
Name	Resistor	Capacitor	Inductor
Image			
Relation	Voltage and current related through Ohm's Law: $$v(t) = i(t)R$$ $v(t) = V_m \cos \omega t$ $i(t) = \frac{V_m}{R} \cos \omega t = I_m \cos \omega t$	**Current** through capacitor is proportional to rate of change of **voltage**. $$i(t) = C\frac{dv}{dt}$$ $$v(t) = \frac{1}{C}\int i(t)dt$$ 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°) 	The current **lags** the voltage (-90°) 

Equivalent Circuit

By considering the power balance of the inverter:

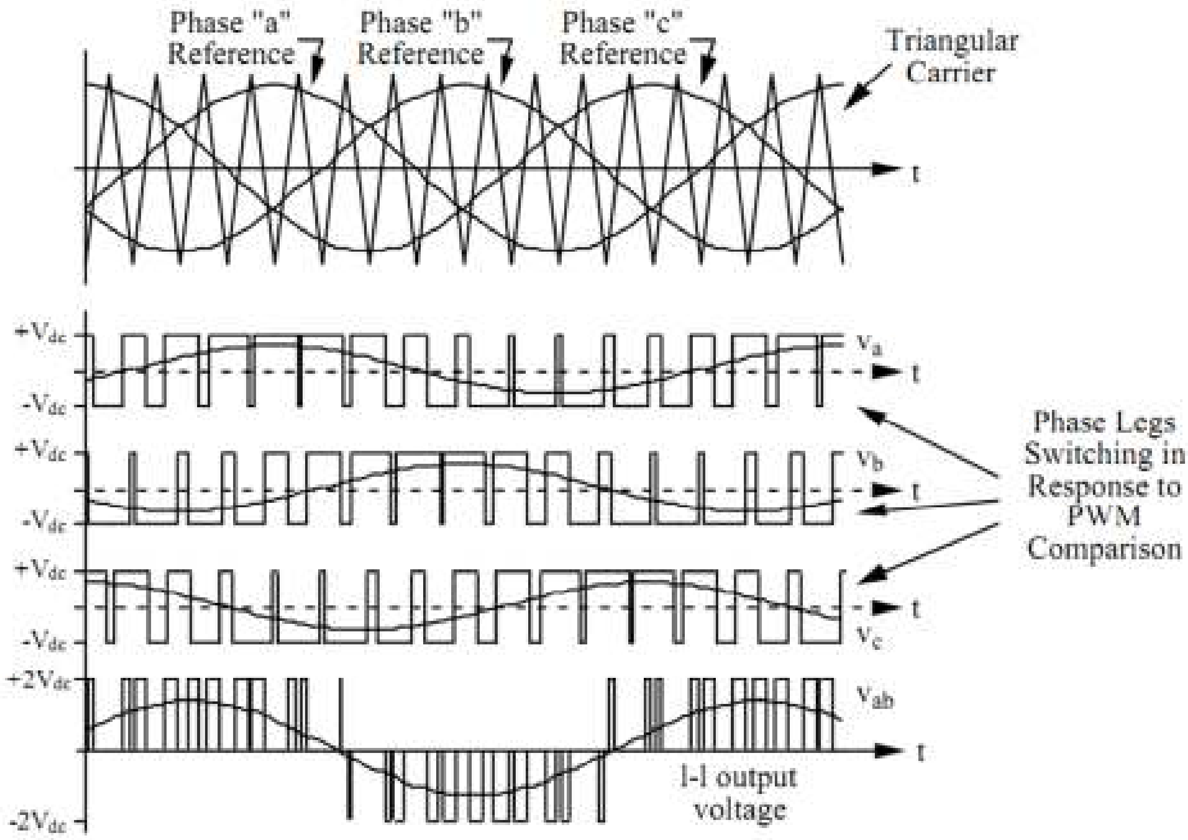
$$DC\ input \rightarrow \qquad 2V_{DC}I_{DC} = 3V_{ph}I_L\cos\theta \qquad \leftarrow 3\ phase\ output$$

- 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.

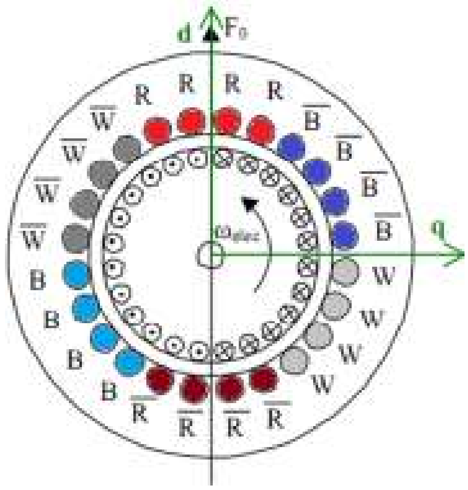


Results in a maximum output magnitude of $V_{LN} = V_{DC}/\sqrt{2}$

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.

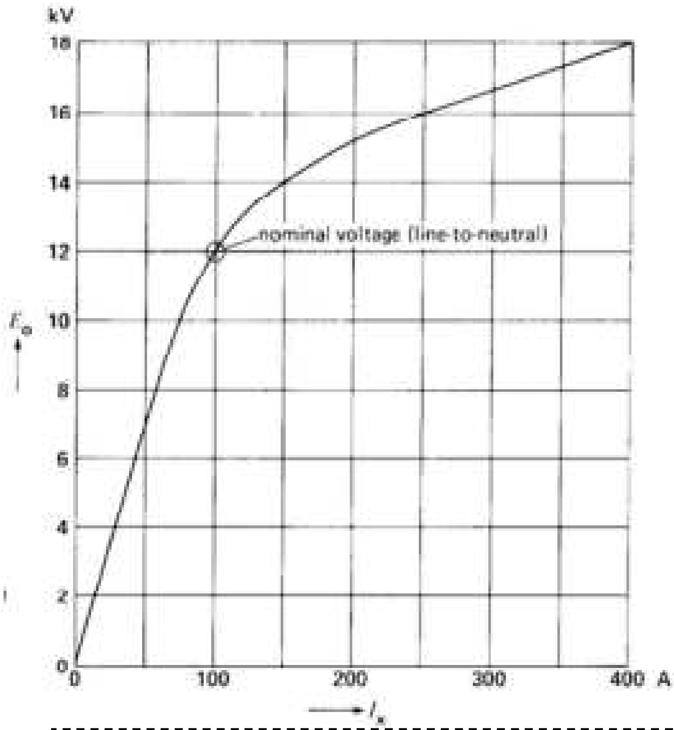
The induced electrical voltage will have angular frequency depending on the rotational speed of the rotor n (in rpm):

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

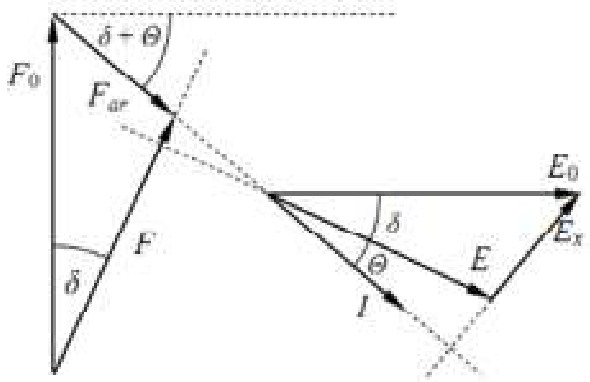
$$E_0 = 4.44 \frac{p}{2} \frac{n}{60} N k_w \phi_m$$

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