Assignment-02

1) With neat Sketch, explain the principle and operation of DC motor drive and Obtain the relation between torque, Speed, Input voltage and back EMF.

DC motor drives have been widely used in applications such as adjustable speeds, good speed regulation and frequent starting, breaking and reversing.

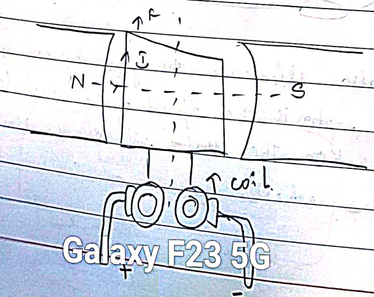
Principle and Operation

When a wire carrying electric current is placed in a magnetic field, a magnetic force acting on a wire is produced. This force is perpendicular to the wire and mag field. F is proportional to the wire length and mag of electric current and density of mag field.

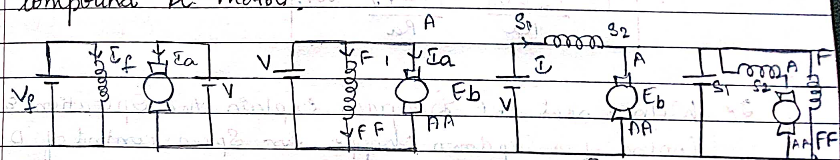
$$\boxed{F = BIL}$$

When the wire is shaped into a coil, the magnetic force acting on both sides produced a torque

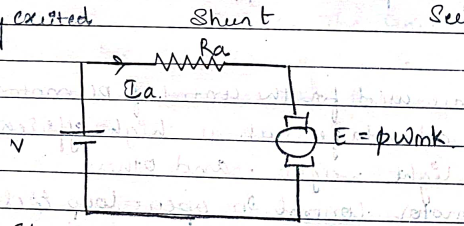
$$\boxed{T = BIL\cos\alpha}$$



where α is the angle b/w coil field and mag field. The mag field may be produced set of windings or permanent magnet. The coil carrying electric current of armature. In order to obtain continuous & max torque slip rings and brushes are used to conduct each wire at the Inclination/position of $\alpha = 0$. Depending on mutual Interconnection b/w field and armature windings. The motors are Surrounded by Seperately shunt, Series & compound DC motor.



Seperately excited   Shunt   Series   Commutative



Steady state Equivalent ckt of DC motor armature.

The basic Equation: $V_a = E_b + I_a R_a$

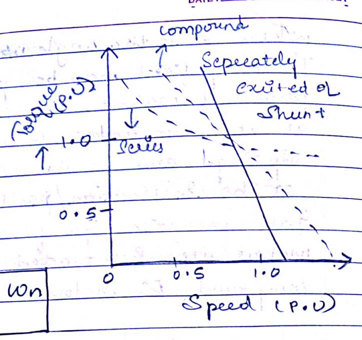
$$E = K_e \phi \omega_m \qquad K_e = \frac{ZP}{60A}$$

$$E = \frac{\phi Z N P}{60A}$$

$$\boxed{T = K_e \phi I_a}$$

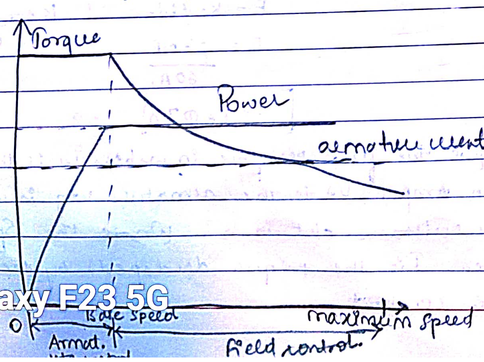
Where ϕ is the flux per pole in webers, I_a is the armature current in Amps. V_A is the armature vtg in volts. R_a is armature resistance ckt in Ω. ω_m is the Speed of armature in rad/sec. T is the torque developed by the motor in Nm. K is the constant.

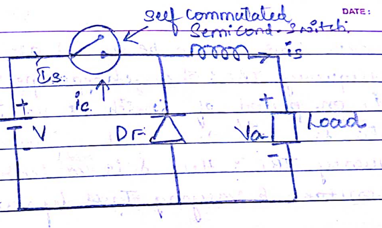
$$V_a = E + I_a R_a$$
$$I_a R_a = V_a - E$$
$$I_a = \frac{V_a - E}{R_a}$$
$$T = K_e\phi\left(\frac{V_a - E}{R_a}\right)$$
$$T = \frac{K_e\phi V_a}{R_a} - \frac{K_e\phi E}{R_a}$$
$$\boxed{T = \frac{K_e\phi V_a}{R_a} - \frac{(K_e\phi)^2}{R_a}\,\omega_n}$$



2) With a neat ckt Diagram, explain the Operation & Control of a Step down chopper for Speed control of DC motor.

Choppers are used for the control of DC motors because of a number of advantages such as high efficiency, flexibility in control, light weight, and others.
For a DC motor control in open-loop & closed loop configurations, the chopper offers a number of advantages due to its high operational frequency.





When the control signal is present, the semiconductor switch S is will conduct, if forward biased. It is assum[ed] that the ckt operation has been arranged such that the removal of i_c will turn off the switch.

During the time on interval of switch $(0 \le t \le \delta T)$, the load is subjected to a voltage V and the l[oad] current increases from i_{a1} to i_{a2}. The switch is opened a[t] $t = \delta T$. During the off period of the switch $(\delta T \le t \le 1)$, load inductance maintains the flow of current through diode DF, the current increases from i_{a2} to i_{a1}. The interval $0 \le t \le \delta T$ is called duty interval.
The direct component or avg value of the load volt[age] V_a is given by

$$V_a = \frac{1}{T}\int_0^T v_a\,dt = \frac{1}{T}\int_0^{\delta T} V\,dt = \delta t.$$

By varying the value of δ b/w 0 & 1, the load [voltage] can be varied from 0 to V.

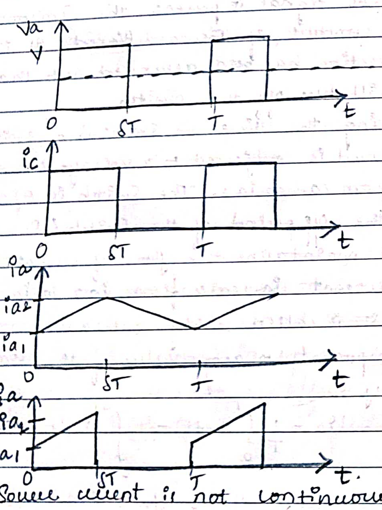
The switch S can be controlled in various ways for varying the duty ratio δ.

1. Time ratio control (TRC)
2. Current limit control (CLC).

TRC (pulse width control) can be varied as:

1. Constant frequency TRC: The chopper period T is kept fixed and the on period of Switch is varied to control the Duty ratio δ.

2. Varied frequency TRC: Here δ is varied either by keeping ton constant & varying T or by varying both ton and T.



* The Source current is not continuous but flows in pulses. The pulsed current makes the peak Input power demand high & may cause fluctuation in the Source voltage.

* The load terminal voltage is not perfect Direct voltage. In addition to a direct component, it has harmonics of the chopping frequency & it multiples. [illegible] also has an AC ripple.

3) With a neat ckt Diagram, explain the multi-Quadrant Control of chopper fed DC motor drives.

The multiquadrant model includes:

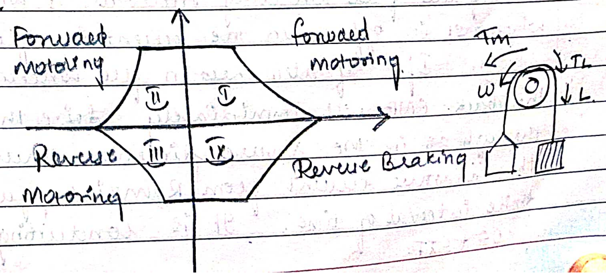
1. Forward Motoring:
2. Forward Braking.
3. Backward motoring.
4. Backward Braking.

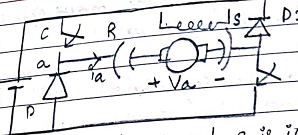
Two Quadrant control of Forward motoring and Regenerative Braking.

A two Quadrant Operation consisting of forward motoring & forward regenerative braking requires a chopper capable of giving a positive voltage and current in either direction.

(a) Single Chopper with a Reverse Switch:-

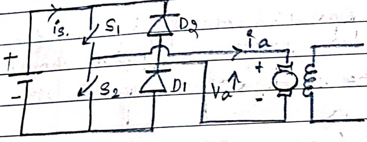
The chopper circuit used for forward motoring and forward regenerative braking is shown, where S is a self-commutated Semiconductor switch, operated periodically such that it remains closed for a duration of δT and remains open for a duration of $(1-\delta)T$. C is the manual switch. When C is closed and S is in Operation, the ckt is similar to that of Forward.





When C is closed and s is in Operation it is permitting the forward motor operation under these conditions terminal A is positive & B is negative Regenerative braking.

Two Quadrant chopper:-



Semiconductor switch S1 and D1 form one chopper and switch S2 and D2 form another shopper & switch S2 and D2 from another chopper.

Discontinuous conduction occurs when the armature current falls to zero and remains zero for a finite interval of time. The current may become zero during the free wheeling interval, it will occur when S1 is off, when the current is flowing to D1.

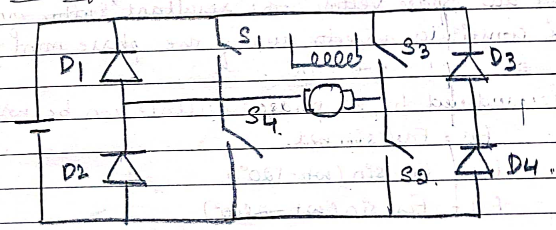
If Ia also zero in free wheeling interval, the back EMF will immidiately drive the current through S2 in the reverse direction. Thus preventing the armature current from Remaining zero for a finite interval of time. It is conducting in interval $0 \le t \le \delta T$.

* During the interval $\delta T \le t \le T$ positive current is carried by D1 & negative current carried by S2.

$$\boxed{I_a = \delta V - E/R_a}$$

* The motoring Operation takes place when $\delta > E/V$ and Regenerative breaking takes place when, $\delta < E/V$
& $\delta = E/V$ is no load condition.

Four-Quadrant Chopper:-



In this chopper, if S2 closed continuously & S1 & S4 are controlled - 2 Quadrant chopper is obtained which provide +ve vtg, & the armature current is either +ve/ -ve torque which gives motor control in Quad 1 & 4.

If S3 is closed continuously & S1 & S4 are controlled then we obtain a 2 Quadrant Operation which can supply Variable negative terminal vtg & armature current can be either positive or negative & motor control in Quad 2 and 3.

DATE : PAGE :

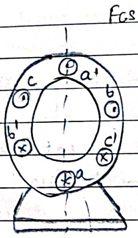
4) With a neat ckt diagram explain the principle & Basic Operation of the Induction motor.

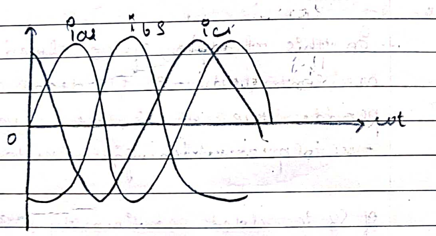
A Below figure Shows a cross Section of the Stator of a three-phase, two pole Induction motor. Each phase is fed with Sinusoidal AC current, which has a frequency of ω and a 120° phase difference between each other as shown.

The currents i_{as}, i_{bs}, i_{cs} in the 3-stator coils a-a', b-b' & c-c' produce alternative mmfs, F_{as}, F_{bs} & F_{cs} which are Space vectors. The resultant Stator mmf vector F_s^s constitutes a vector sum of the phase mmf vectors.

The mmfs produced by the phase currents can be written as

$$F_{as} = F_{as}\sin\omega t.$$
$$F_{bs} = F_{bs}\sin(\omega t - 120°)$$
$$F_{cs} = F_{cs}\sin(\omega t - 240°)$$





Stator resultant mmf vector, F_s^s, is expressed as

$$F_s^s = F_{as}e^{j0°} + F_{bs}e^{j120°} + F_{cs}e^{j240°}$$

$$F_s^s = \frac{3}{2}F_s e^{(\omega t - 90°)}$$

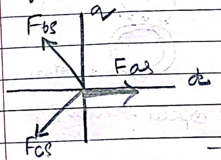
This the Magnitude of 3 phase.

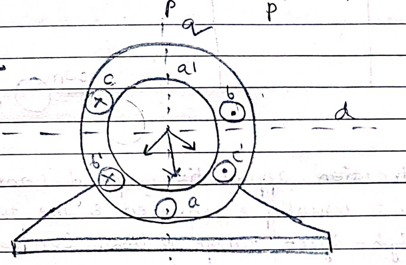
DATE : PAGE :

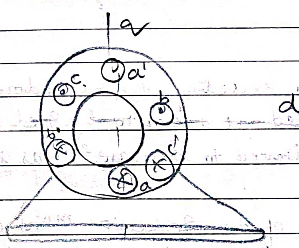
This Indicates that the resultant stator emf vector is rotating with a frequency of the angle of velocity of ω, & its magnitude is $(3/2)F_s$.

The frequency ω or angular velocity of the rotating stator mmf in the equation depends only on the frequency of the alternative current of the stator.

$$\omega_{ms} = \frac{2}{P}\omega = \frac{4\pi f}{P} \text{ rad/sec.}$$







$$\omega_{sl} = \omega_{ms} - \omega_m > 3 \omega_{ms}'$$

where ω_{sl} is called slip Speed. The parameters, & known as slip

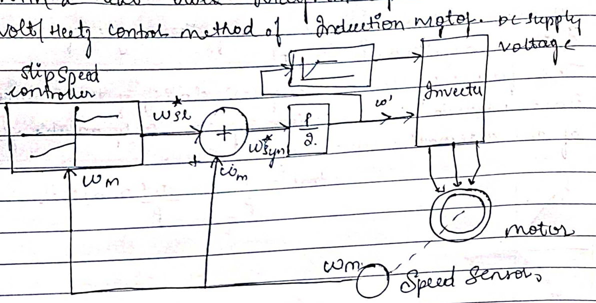
$$s = \frac{\omega_{ms} - \omega_m}{\omega_{ms}} = \frac{\omega_{sl}}{\omega_{ms}}.$$

$$\omega_r = \frac{\omega_{sl}}{\omega_m}\omega = s\omega$$

$\omega_r \rightarrow$ frequency of the rotor voltage.

DATE: PAGE:

5) With a neat block Diagram explain the constant volt/Hertz control method of Induction motor.



In traction application, Speed control in a wide range is usually required & the torque demand in the high-Speed range is low. Control beyond constant power range is required.

To prevent the torque from exceeding the breakdown torque, the machine is Operated at a constant Speed & the machine current & power are allowed to decrease slip as shown.

The Speed torque characteristic of an Induction motor can be simultaneously controlling the V/f & frequency → known as constant volt/Hertz control.

$$I_{mr} = \frac{E}{X_m} = \frac{E_{rated}}{\omega_r L_m}.$$

DATE: PAGE:

$$I_r' = \frac{(\omega/\omega_r)\, E_{rated}}{jL_r\omega + R_r'/s}.$$

The torque produced can be obtained as

$$T = \frac{3}{\omega} I_r'^2 R_r'/s = \frac{3}{\omega}\left[\frac{(\omega/\omega_r)^2 E_{rated}^2 R_r'/s}{(R_r'/s)^2 + (L_r\omega)^2}\right]$$

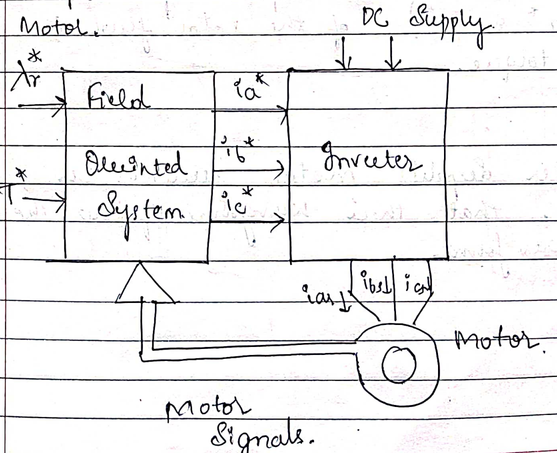
The slip s_m corresponding to the maximum torque is

$$s_m = \pm \frac{R_r'}{L_r\omega}$$

& then the max torque is given by

$$\boxed{T_{max} = \frac{3}{2}\,\frac{E_{rated}^2}{L_r\omega_r^2}}$$

6) Explain the Field Orientation control of Induction Motor.



-tation

The field Oriented principle defines the condition of optimal torque production, the orthogonality of Rotor current and flux must be maintained all the times.

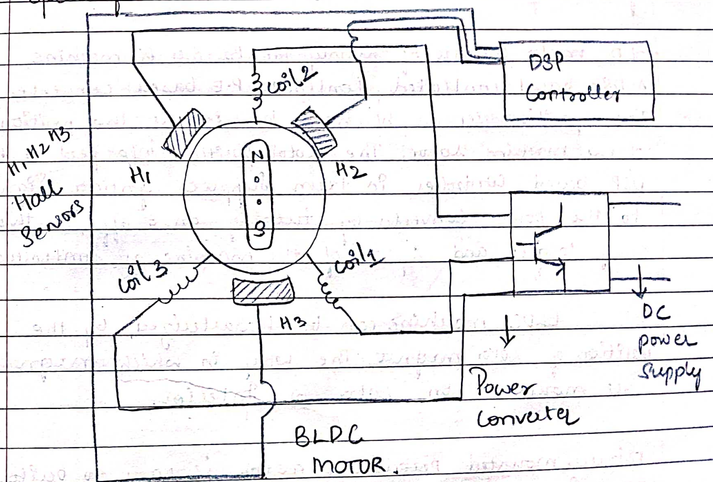
In the Steady State the rotor set is down in Such a Speed that all developed torque matches the Load torque, at the transient conditions in order to meet the field orientation principle, Special techniques are required to provide algorithmic equivalent of actual physical disposition b/w Stator & Rotor fields.

The field Oriented System produces reference Signals (I_{as}^* I_{bs}^* I_{cs}^*) of the Stator currents based on the Input reference values (λ_r^* & T^*) of the rotor flux & the motor torque.

An Inverter supplies motor currents i_{as}, i_{bs} & i_{cs}, that their waveforms follow the reference waveforms.

7) With a neat Diagram explain the construction & principle of the BLDC motor Drives.

* BLDC Motor consists of mainly the Brushless DC Machines, A DSP based controller, power electronics based power converter.
* The position Sensors give (h1, h2, h3) senses the position of machine rotor.
* The Rotor position information is feed to the DSP based controller in turn supplies gating Signals to the power converter by turning on & off proper stator pole windings of the machine, In this way torque & Speed of the machine are controlled.



DATE: | | PAGE:

BLDC machine can be characterized by the position of permanent magnet, The way in which magnets are mounted on rotor Surface / Interior.

Surface mounted permanent motor is easy to build as easily magnitized on the surface mounted for type to minimize logging torque.

There is a possibility that it will fly away using high Speed Operation.

8) With a neat block Diagram explain the torque control of BLDC motor drives.

BLDC motor consists of mainly the Brushless DC machine, A DSP based controlled, controller, P.E based converter The position sensors h1, h2 & h3 sensors, the position of the machine rotor. The Rotor position into feed to the DSP based controller in term supplies gating Signals to the power converter by turning on & off, in this way torque and speed of the machine are controlled.

BLDC machine can be characterized by the position of rotor magnet. The way in which magnets are mounted on rotor or Interior.

Source mounted permanent motor is easy to build as Specially Skewed poles are easily magnitised

DATE: | | PAGE:

There is a possibility that it will fly away using high Speed Operation.

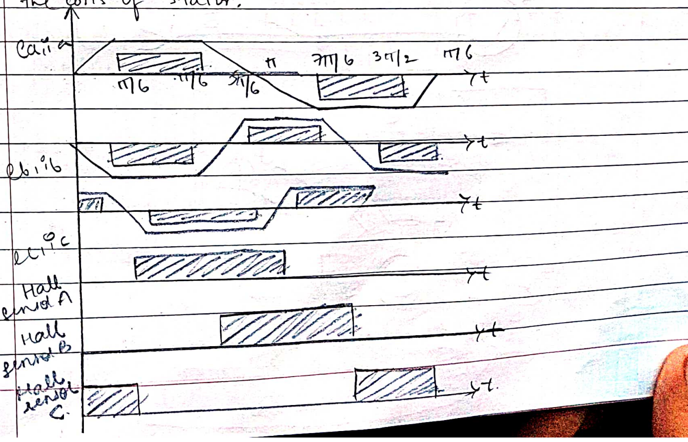
Interior mounted rotor is good for high Speed operation The Induction variation is varied for this type of rotor because the permanent magnet path is Equivalent to air in the magnetic circuit. Two major clashes of BLDC.

① Trapezoid : The Shape back emf BLDC motors are designed to develop Trapezoidal Back EMF & their ideal characteristics are:

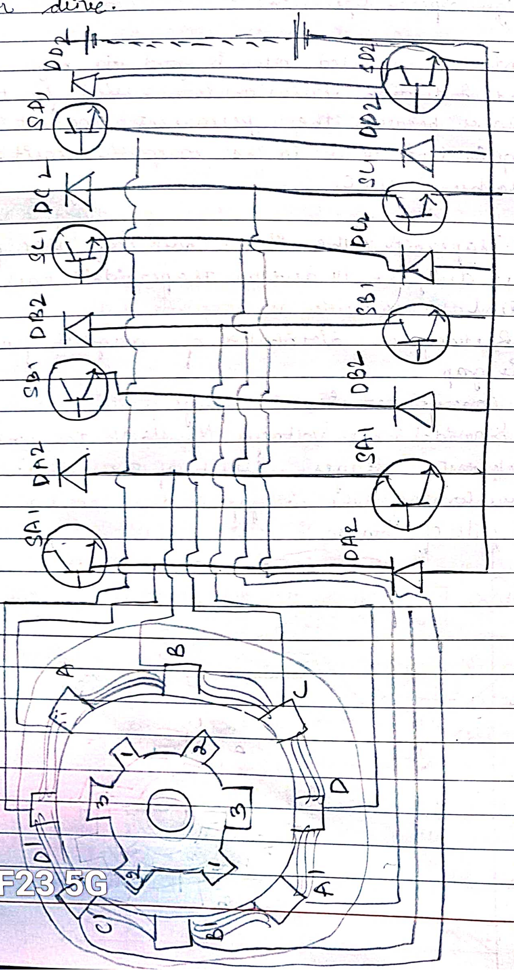
* Rectangular distribution of magnetic flux in the air gap.

* Concentrated Stator windings.

② Sinosidal :- The voltages V_a, V_b, V_c the link to Neutral Back EMF voltages, result of the permanent magnetic flux coming the air gap in the Direction & cutting the coils of Stator.



9) With a neat ckt Diagram of Switched Reluctance motor drive.

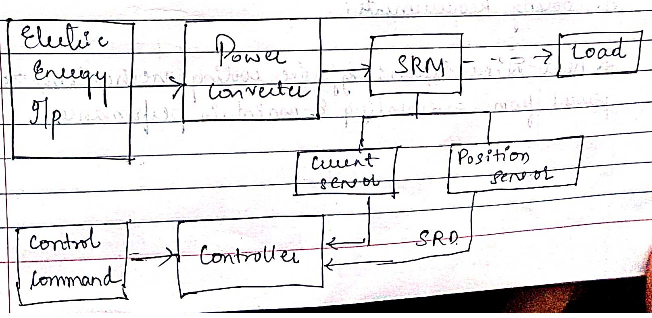


SRM's are consider to be attractive for variable speed drive application due to its shape of rugged structure, reliable converter topology, high efficiency over a wide speed range & simple in control. These are suitable for EV's, electric traction applications, mining drives, door actuators etc.

Conventional SRM drives consists of SRM, power inverter, sensors such as voltage, current & position sensor & control circuitory such as DSP controller & its peripherals.

The SRM drive inverter is connected to DC supply which can be utilized from utility lines through Diode Rectifiers.

The control ckt provides the gating signal through the switches of inverters according to the particular control strategies.



DATE: / / PAGE:

10) Discuss the factors to be considered for selection & sizing of electric motors for EV applications.

1. Power and Performance:

* Torque and Speed: Adequate torque for acceleration & climbing, appropriate speed for efficient operation.

* Power rating: Sufficient to meet driving requirements & ensure performance under various conditions.

2. Efficiency:

* Energy consumption: High efficiency to maximize battery life & range.

3. * Size and weight.

Compactness & weight: The motor should fit within space constraints & be lightweight to not compromise the vehicle's range.

4. Cooling Requirements:

* Heat Dissipation: Effective cooling mechanisms to prevent from overheating & maintain performance.

DATE: / / PAGE:

5. Reliability & Durability:
* Lifespan & Maintainence: long life span & minimal maintainence requirements.

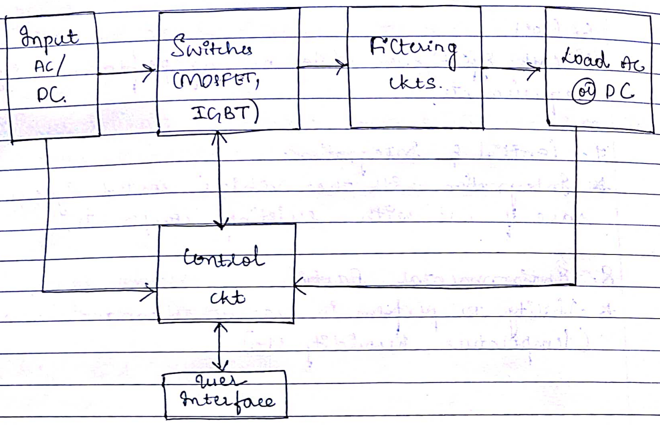
6. Cost
* Cost - Effectiveness while meeting performance & efficiency requirements.

7. Control & Integration:
* Integration with the vehicle's control systems and ease of use with existing components.

8. Environmental Factors.
* Ability to perform in various environmental conditions (temperature, humidity, etc).

Module-3

① Discuss the power electronics converter in EV application, mention their requirements & limitations.



Power Electronics is a discipline that studies power converter which process & control power flow by means of electronics. It involves the use & control of power setting conductor switches such as power diodes, IGBT's, MOSFET's. power converter will consists of 4 segments switching & peripheral ckts, control ckts, feedback & optional user interface.

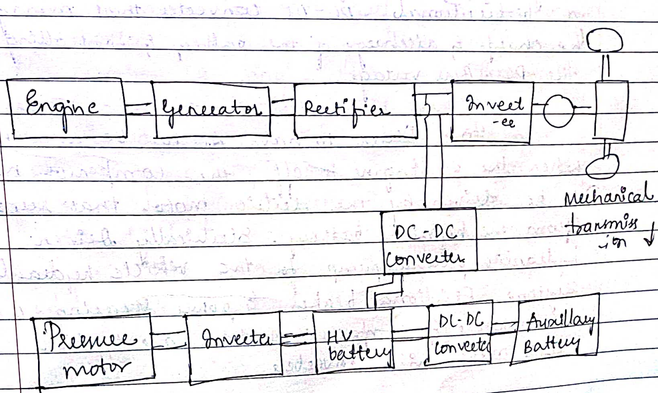
Power converter are classified by the input & output which can be either AC/DC they can be 4 types of power converters. DC to DC converter, DC to AC inverter, AC to DC Rectifier, AC to AC cyclo converter. The 1st 3 types of converters are used in HEV's AC to AC conversion involves AC to DC ckt & DC to AC ckt 's not unusual. Depending on power drive configuration, HEV's can involve one or more power converter of different types.

Main circuit:- It consists of power semiconductor devices & are used to control turn on & turn off at a frequency of few kHz to 100's of kHz

Filtering circuits:- P.E converter usually involve low pass filter that will filter out the high frequency component.

Control & F/B circuit:- It usually involves a use of micro-controller & sensors.

② With a neat block diagram, explain the schematic of power converter used in electric vehicle application.



Power electronics is the one of the technology propelling the shift from conventional IC Engine power vehicles to electric & fuel cell based vehicles.

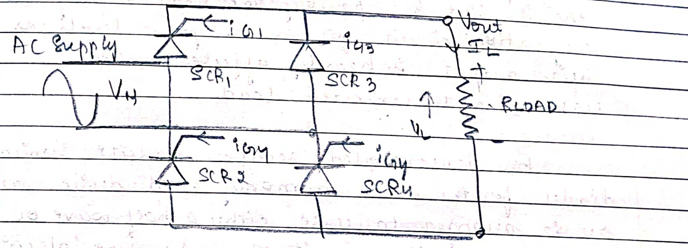
In the series HEV, the IC Engine drives the three phase permanent Magnet sync. generator whose o/p is a 3-ϕ voltage with a variable frequency & variable voltage that this output voltage is need to be rectified to DC. The front wheel are driven by an I.M which needs to be controlled by a vtg Source Inverter or current Source Inverter.

The Energy Stored is connected to the DC Bus b/w a generator & Rectifier output as a Inverter. There is a bidirectional DC-DC converter that manages the charge & discharge of the Battery & controlling the DC Bus voltage.

In: Order to have AC to be running when the IC Engine is off, the compressor need to be driven by the electric motor that runs from the hybrid battery. Electrically Driven hydraulic pressure pump for the vehicle hydraulic Systems. Frictional brakes & power steering. The AC motors & compressor motors are typical BLDC motors with Inverters.

Galaxy F23 5G

③ With a neat circuit Diagram explain the Operation of Single phase rectifier for the HEV applications.



Rectification of converts an Oscillating sinusoidal AC voltage source into a constant current DC voltage supply by means of diodes, thyristors, transistors or converts. This rectifying process can take on many form with half wave, full-wave, uncontrolled and fully-controlled rectifiers. transforming a single phase or three-phase supply into a constant DC level. In this Rectifiers are one of the basic building blocks of AC power conversion with half-wave or full wave rectification generally performed by semicond-uctor diodes. Diodes allow alternating currents to flow through them in the forward direction while blocking current flow in the reverse direction creating a fixed DC voltage level making them ideal for rectification.

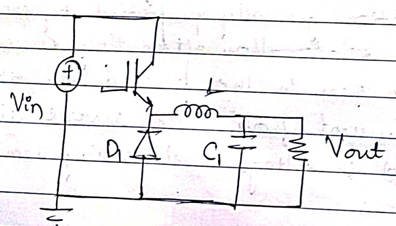
DATE: PAGE:

All single phase rectifier use solid · state devices as their primary AC-to-DC converting device. Single phase uncontrolled half-wave rectifiers are the simplest & possibly the most widely used rectification circuit for small power levels as their output is heavily affected by the reactance of the connected load.

For uncontrolled rectifier circuits, semiconductor diodes for the most commonly used device and are so arranged to create either a half-wave or full wave rectifier circuit. The advantage of using diodes as the rectification device is that by design they are unidirectional devices having an inbuilt one-way pn-junction.

The pn-junction converts the bi-directional alternating supply into a one way unidirectional current by eliminat-ing one-half of the supply.

4) With a neat circuit diagram explain the operation of Buck converter for the HEV application.



DATE: PAGE:

Buck converter:-

Buck Converter will step down the higher voltage DC input to a lower voltage DC output.
In an HEV it stepdown the hybrid battery voltage (200-400V) to charge the auxillary battery (14V).

The uniqueness in the last difference between the input or output of the converter & small duty ratio of 3.5% needed to be controlled for switching. A circuit consists of switch, a free wheeling diode & a filter. A small duty ratio will make control and regulation very difficu[lt] It also affect design of L, C current Ratio.

We assume Ideal components the voltage drop is zero when turned on & also o/p voltage is constant when switch is turned on, the vtg across the inductor is

$$V_L = V_d - V_o.$$

when switch is turned off and circuit is considered as in continous mode of operation the voltage drop across the inductor is $V_L = -V_o$.

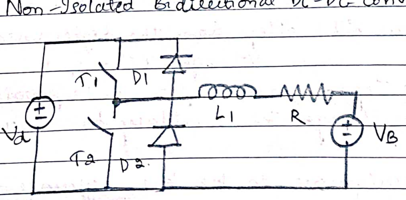
In study state operation, the avg voltage of the inductor is zero.

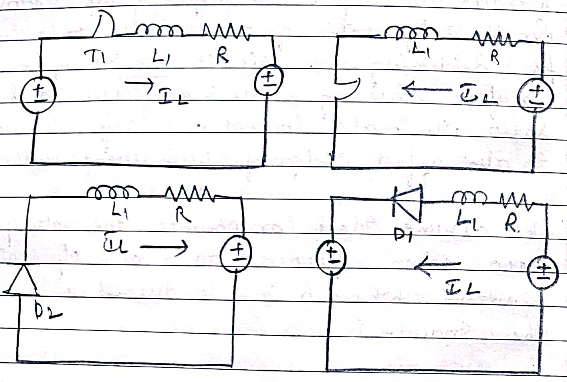
$$(V_d - V_o) DT = V_o (1-D) T_s \;\&$$

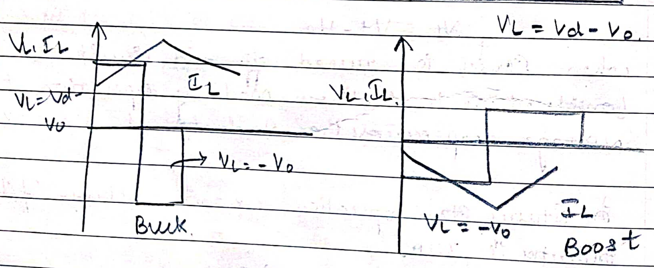
$$V_o = DV_d.$$

The current ripple is $\Delta I_L = \frac{1}{L} V_o (1-D) T_s$.

(5) With a neat circuit diagram explain the operation of Non-Isolated Bidirectional DC-DC converter for the HEV applications







In a Buck Operation power is transfered from V_d to V_B, when T_1 is closed and T_2 is Opened, Since $V_D > V_B$, $V_L = V_d - V_o$ & the Inductor current I_L builds up. when T_1 is opened the Inductor current I_L continuously flow throw D_2. Then $V_L = V_B$, At constant V_o, the Inductor current over one cycle in study state operation will remain same,

$$\int_0^{t_{1ON}} (V_d - V_o)\,dt = \int_{t_{1ON}}^{t_{1ON+OFF}} (-V_o)\,dt$$

$$V_o = \frac{t_{ON}}{T} V_d = D_1 V_d.$$

$$\boxed{D_1 = \frac{t_{ON}}{T}}$$

D is the duty ratio defined as the percentage of the time of the Switch T_1.

Boost Operation The power is transfered from V_B to V_o when T_2 is closed & T is Opened. V_B & Inductor form a Short circuit through the Switch T_2 Therefore $V_L = V_B$ & the Inductor current I_L builds up when T_2 is Open. the Inductor current continuous to follow to D_1 to V_D

Therefore $V_L = V_D - V_B$

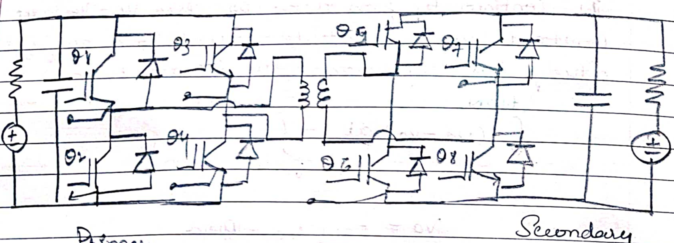
$$\int_0^{t_{2ON}} V_o\,dt = \int_{t_{2ON}}^{t_{2ON}+t_{2OFF}} (V_d - V_o)\,dt$$

$$V_d = \frac{1}{1-D_2} V_o \Rightarrow \frac{t_{2ON}}{T}$$

$$D_2 = 1 - D_1$$

DATE: PAGE:

(6) With a neat circuit diagram Explain the operation of Isolated Bidirectional DC-DC Converter for the HEV application.



The primary bridge Inverter Switches at 20-50 kHz with 50% duty ratio. The o/p of the primary is Square wave vtg which is of the primary winding of the Isolation transformer. The Secondary winding of the transformer will have Square wave voltage without any control at the gating or the Secondary, the bridge Converter the voltage of the Secondary of the transformer is rectified through the H-free wheeling diodes. The output voltage will fluctuate with the load conditions & the 1° voltage with it.

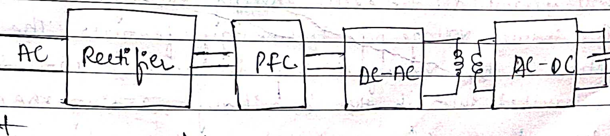
Basic Principle & Steady state Operation

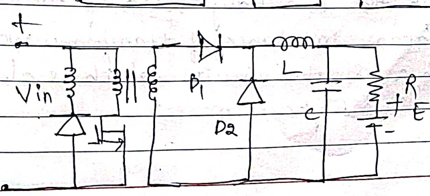
The Operating modes of Isolated Bidirectional DC-DC Converter is distinguished according to the phase Shift angle, load condition & output voltage. The dead-band & Switching frequency is fs. we define Ts at one half of the Switching frequency fs ie $T = \frac{1}{2} f_s$. The Duty cycle of phase Shift is based on period, $D = \frac{t_{ON}}{T_s}$.

Therefore DT_s is The phase b/w the two bridges, I_L is the current of the leakage Inductance of the Secondary winding. The output voltage of the Secondary bridge is V_2.

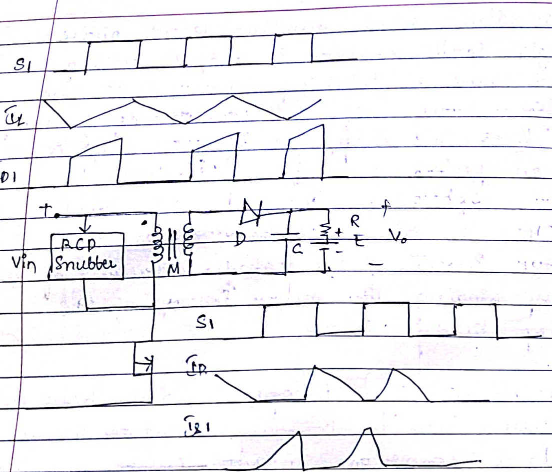
There are no of different operating mode based on output current with the boundary conditions & under heavy load condition, Inductor current Increase from the Initial negative value $i(t_0) < 0$ at the beginning of Switching cycle & reaches a positive value $-i(t_0)$ at the end of the half cycle.

(7) With a neat Circuit Diagram explain the Operation of Forward/ Flyback converter for the HEV application.





Forward converter

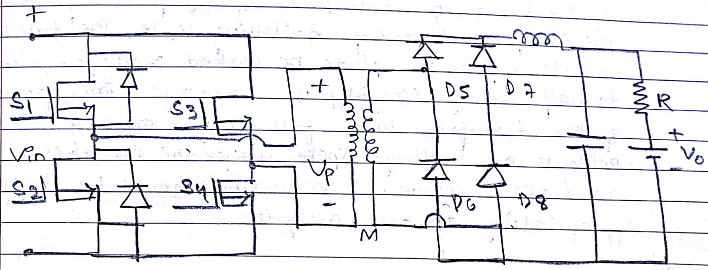


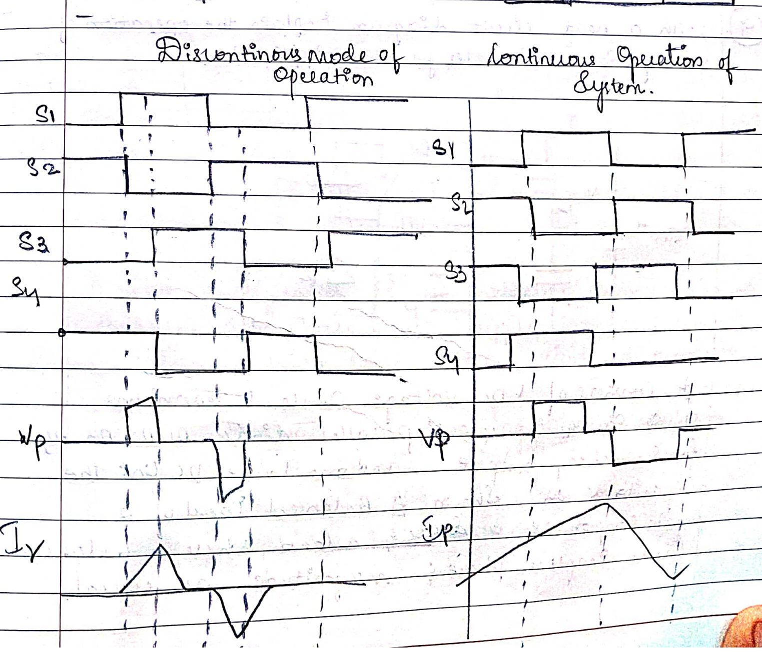
Flyback converter.

In Forward & flyback converter R is the battery Internal Resistance, E is the battery Internal voltage & Vo is the output across the battery. The Operation then same as Bug converter

The S1 switch turn off the leakage Inductance of transformer will exhaust all the excess energy through the Switches. This induces voltage pipe technology features. The energy Stored in the manufacturing inductance would be exhausted. through the auxillary winding. the excess energy in the Leakage Indutance of transformer would be mitigated through Snubber circuit which is also needed through in a Flyback converter.

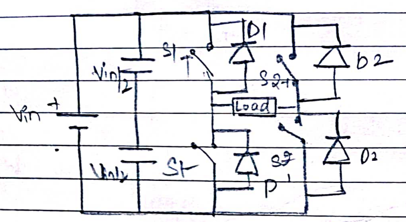
(8) With a circuit diagram explain the Operation of Full Bridge DC-DC converter for the HEV Applications.





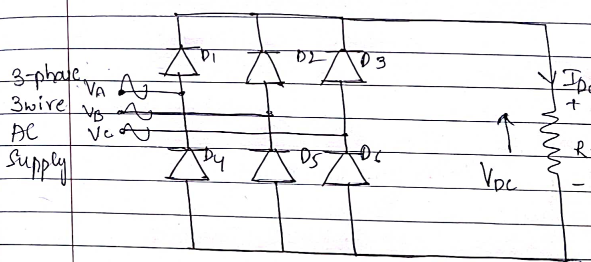
Opeeation of Full Bridge DC to DC converter is compared to half bridge converter. Where only half of the DC voltage is imposed on the primary side of the transformer in every switching cycle, the full bridge converter utilize the whole DC linked voltage. Similar to half bridge converter the leakage Inductance of the transformer in a full bridge converter does not contribute any voltage spike across the switches. The leakage reactance Inductance should be designed appropriately for best designs.

(9) With a neat circuit diagram explain the operation of voltage Source Inverter for HEV Application.



It Consists of 1 DC voltage Source, 4 transistors S1, S2, S3, S4 & 4 anti-parallel diodes D1 D2 D3 D4 for Switching purpose and one large DC link the Capacitor as Shown. A Balanced Load of 2 main Components a Source & a load, where a balanced Source implies phase & magnitude are equal and are phase shifted by 120 degrees. According to the KCL principle, the balanced load implies all the load Impedances in all the 3 phases are equal in Magnitude and phase. The thyristors T1 T3 & T5 supply current.

10) With a neat circuit diagram explain the Operation of 3-φ rectifier for the HEV application.



3-phase rectification is the process of converting a balanced 3-phase power supply into a fixed DC supply using solid state diodes or thyristors.

We saw in that the processing of AC conversion to DC called Rectification with the most popular Circuits used to perform this rectification process is one that is based on solid-state semiconductor diodes.

DATE : / / PAGE :

Int fact rectification of alternating voltages is one of the most regular applicatione of diode as diodes are inexpensive, small & robust allowing us to create numerous type of rectifier circuits using either individually connected diodes or with just a single integrated bridge rectifier module.