Unit 1

Electrical drive : Motion control is required in large no of industrial and domestic application like transportation system, rolling mills, paper m/c, textile mills, m/c tools, fan, pumps, washing m/c etc

System employed for motion control are clas drives & may employ any of the prime movers such as diesel or petrol engines, gas or steam turbines, steam engine, hydraulic motors & electric motor for supplying mechanical energy for motion control.

Drives employing electric motors are k/as electrical drives.

This prime mover supplies the mechanical energy to the drive for motion control

⇒ Block Dig

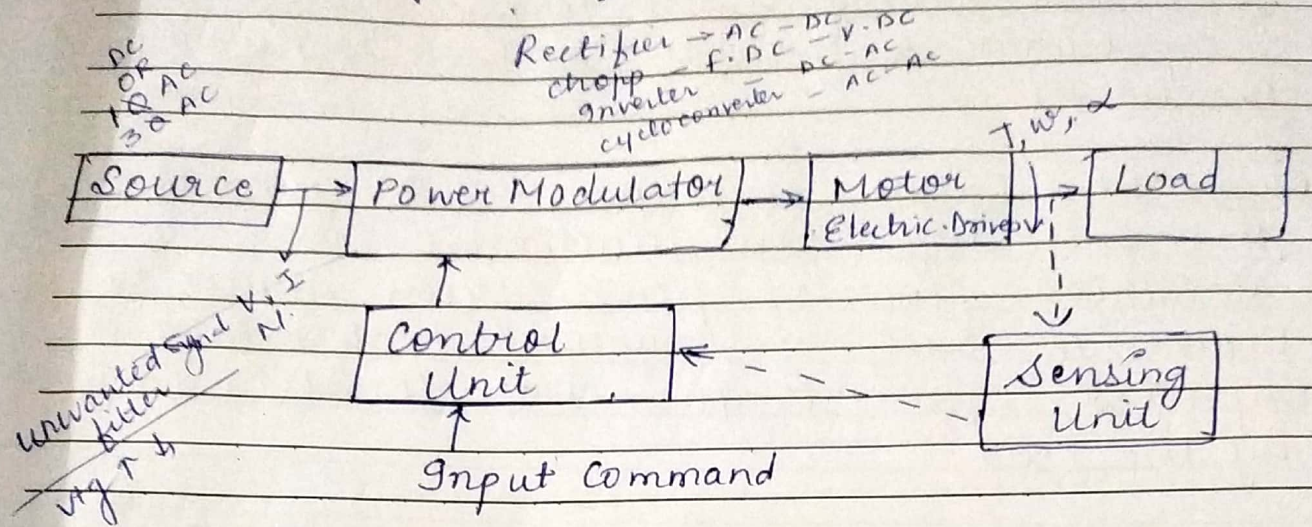
Control Unit : The control unit controls the power modulator which operates at small voltage & power levels.

The control unit also operates the power modulator which operates at small voltage & power levels. The control unit also operates the power modulator as desired. It also generates the commands for protection of power modulator & motor.

An I/P command signal which adjusts the operating point of the drive from an input to the control unit

Sensing unit: It senses the certain drive parameter like motor current & speed. It is required for protection

⊛ Block diagram of Electrical Drive



Motion control is required in large no of industrial & domestic applications like transportation system, rolling mills, paper machines, textile mills, machine tools, fan, pumps, robots, washing machines etc.

Systems employed for motion control are c/as drives and may employ any of the prime movers such as diesel or petrol engines, gas or steam turbine, steam engines, hydraulic motor & electric motors. Drives employing electric motors are k/as electrical drives.

load is usually a machinery designed to accomplish a given task eg fan, pump, robots, washing machine, machine tool, Usually load requirements can be specified in terms of speed & torque demand.

A motor having speed torque characteristics & capabilities compatible to load requirements is chosen.

Power Modulator performs one or more of the following four functions
1) Modulates flow of power from source to motor in such a manner that motor is imparted speed torque characteristics required by the load.

2) During transient operation such as starting, braking & speed reversal, it restricts source & motor within permissible values, excessive current drawn from source may overload it or may cause a voltage dip

3] Converts electrical energy of the source in the form suitable to the motor eg if source is dc and an induction motor is to be employed then the power modulator is required to convert dc into a variable frequency ac.

4] Selects the motor of operation of motor ie motoring or braking

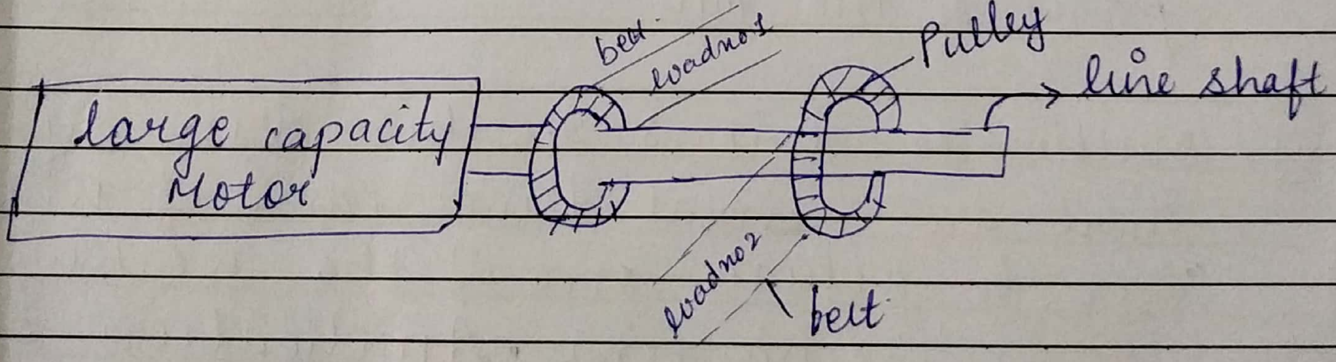
Power modulator is employed to perform function and it is clas convertor & it depend upon its circuit. Controls for power modulator are built in control unit which usually operates at much lower voltage & power level.

Ques: classification of Electrical drives

Electrical drives in industrial application are classified into three types

1) Group drive
2) Individual drive
3] Multi Motor drive

1] Group drive : This drive consist of a single motor which drives one or more line shaft supported on bearing. The line shaft may be fitted with either belt by means of which a group of m/c or mechanism may be operated. It is sometimes clas shaft drive



Advantage : 1) A single large motor can be used instead of no of small motors

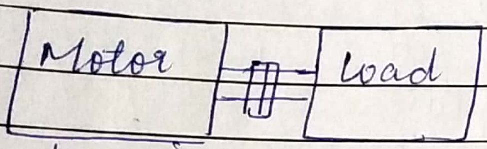
2) The rating of single large motor may be approximately reduced by taking into a/c the diversity factor of load.

Disadvantages: 1) There is no flexibility if the single motor used develops faults then the whole process will come to stop.

2] Addition of extra m/c to the main shaft is difficult.

3] If some of the machines are not working the losses are increased thus decreasing the efficiency & power factor.

2] Individual Drive: In this drive each individual m/c is driven by a seperate motor. This motor also impart motion to various other parts of the m/c



3] Multimotor drive: In this drive system there are several drives each of which serve to actuate one of the working parts of mechanism. Application of such drive is in complicated ~~motor~~, metal cutting, m/c tools, paper m/c, rolling mills etc

This type of multimotor incorporates three motors
1) For vertical
2) For side moment
3) For forward moment of the load

Each of this drives.

Ques Compare DC & AC drive

DC drive	AC drive.
1) Fast response & wide speed range, smooth control	1) Response depend upon the type of control
2) line commutation of converter is used	2) Force commutation
3] The commutator makes the motor bulky, costly & heavy	3] The commutator is absent in AC drive so it is cheap
4] Frequent maintenance is required	4] It require less maintenance
5] Self starting	5] Not self starting
6] It is used to control DC O/P	6] It is used to control AC O/P
7] It have converter only	7] It has both converter & inverter
8) Speed ctrl is done by changing freq	8] Speed ctrl is done by armature ctrl & field control

Q Advantages of Electrical Drives

Electrical drives are widely used bcoz of the foll advantages.

1) They have flexible control characteristics the steady state & dynamic characteristics of electrical drive can be shaped to satisfy load requirements.

2] Speed can be controlled in limit.

3] Electric braking can be employed & control gear required for speed control, strating, braking is usually simple & easy to operate.

4] Availability of semiconductor converters employing thyristor, IGBT, digital IC have made the control characteristics even more flexible.

5] It is possible to reshape characteristics of drives almost to meet load requiremen

6] Drives can be provided with automatic fault detection system.

7] PLC & computers can be employed to automatically control the drive operation in desired sequence

8) They are available in wide range of torque, speed & power.

9) Electric motors have high efficiency & can be made compatible with load.

10) They are adaptable to almost any operating condition such as explosive, radioactive environment.

11] Do not pollute the environment

12] Can operate in all four quadrant of speed torque plane.

13] Unlike other prime movers there is no need to refuel or warm up motor. They can be started instantly & can immediately be fully loaded

Disadvantages of Electrical drive

1) The application of drive is limited bcoz it cannot use in place where the power supply is not available

2] It can cause noise pollution

3] Initial cost of system is high

4] It has poor dynamic response

5] O/p power obtained from drive is low

6] During breakdown of condr or short ckt the system may get damaged due to which severals problems occur

Application: It is used in large no of industrial & domestic application like transportation system, rolling mills, paper m/c, textile mill, machine tools, fans, pumps, washing M/c. etc

Ques : Basic Requirements of Electrical braking

The brake is an equipment to reduce the speed of any moving or rotating equipment like vehicle, locomotives. The process of applying brakes is termed as braking.

Braking is necessary to break the motor rapidly & smoothly acc to given speed schedule. We know that there are various type of motors available (DC motor, I. motor, synchronou motor, single phase motor) & the properties of these motors are different from each other. hence braking method also differs from each other. The main idea behind each type of braking is the reversal of direction of flux.

E. Braking are classified into three

1) Regenreative Braking

2) Plugging type braking

3) Dynamic or Rhiostatic braking

Regenerative Braking :

Regenerative braking takes place whenever the speed of the motor exceeds the synchronous speed. hence the back emf exceeds the supply vtg hence the motor works as a generator & supply itself power from load ie motors. this is clas a regenerative braking.

The condition for regenerative braking is that the rotor has to rotate at a speed higher than synchronous speed, only then the motor will act as a generator & the direction of current flow through the circuit & direction of the torque reverses & braking takes place.

The only disadvantage of this type of braking is that the motor has to run at super synchronous speed which may damage the motor mechanically & the electrically but regenerative braking can be done at sub synchronous speed if the variable frequency source is available

$$I_a = \frac{V - E_b}{R_T}$$

$$R_T = R_a + R_b$$

$$I_a = -\left(\frac{E_b - V}{R_T}\right) = -I_a$$

The motor torque consequently changes its sign & motor develop a breaking torque.

$$T \propto \phi I_a$$

$$T = K \phi I_a$$

$$T = -K\phi I_a$$

$$T = -T_B \quad \text{at } \omega > \omega_0$$

The speed torque characteritics eqn in case of regenerative breaking

$$W = \frac{K}{K \cdot \phi} + \frac{R_T \cdot T_B}{(K\phi)^2}$$

2) Dynamic braking or Rheostatic braking

It is also klas Rhostatic braking. In this type of braking the DC motor is disconnected from the supply & a braking resistor Rb is immediately connected across the armature.

The motor will now work as a generator & produces the braking torque.

During electric braking when the motor works as a generator the kinetic energy stored in the rotating parts of the motor & connected load is converted into electrical energy.

It is disspated as heat in the braking resistance Rb and armature resistance Ra.

Dynamic braking is an inefficient method of braking as all generated energy is dissipated as heat in resistance.

⇒ The supply to the field wdg is maintained but the arm is disconnected from the supply vtg & reconnected to an external resistance (Rdb). The m/c now acts as an generator converting KE ~~Stored~~ in its moving parts to electrical energy which is dissipated as it in the external resistance

This method of braking is clas dynamic or Rheostatic braking.

Since the supply vtg V=0 & polarity of back emf remains unchanged, the arm current during dynamic breaking is given by

$$V = E_b + I_a(R_a + R_{db})$$

$$I_a = \frac{V - E_b}{R_a + R_{db}}$$

V=0 (during breaking)

$$I_a = \frac{-E_b}{R_a + R_{db}}$$

-ve sign shows that arm current is reversed

The dynamic breaking torque can be expressed as

$$T_{db} \propto \phi I_a$$

$$T_{db} = K\phi I_a$$

$$I_a = \frac{-E_b}{R_a + R_{db}}$$

$$T_{db} = K\phi \left(\frac{-E_b}{R_a + R_{db}} \right)$$

$$E_b \propto \phi \omega$$

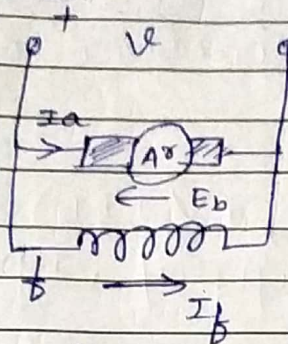
$$E_b = K\phi\omega$$

$$T_{db} = K\phi \left(\frac{-K\phi\omega}{R_a + R_{db}} \right)$$

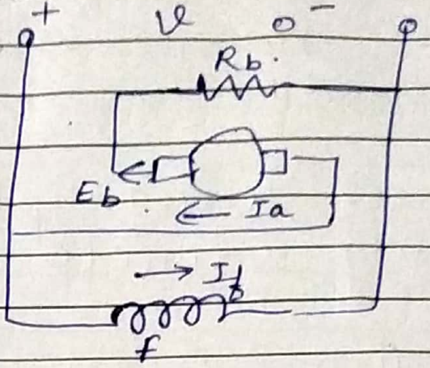
$$T_{db} = -\frac{(K\phi)^2 \omega}{R_a + R_{db}}$$

3) Plugging or Reverse current braking

Fig :



Normal



In this armature terminals of a seperately excited or shunt m/c when running are reversed.

Therefore in plugging the supply vtg V & induced voltage Eb is c/as back emf which act in same direction

Thus during plugging the effective vtg across the armature will be (V+Eb) which is almost twice the supply vtg.

The armature current is reversed & a high braking torque is produced. An external current limiting resistor is connected in series with armature to limit the armature current to a safe value.

Application 1) Controlling Elevator
2) Rolling Mill
3) Printing Press.

1) In normal case the direction of back emf is opp to armature current but in case of braking the direction of back emf is same as direction of armature current

2) Thus during plugging, (V + Eb) is armature vtg, is double the supply vtg.

3) Thus high current flow in the armature ckt during braking so we use external resistance Rb in series with armature

4) At time of braking, K.E & energy given by supply is dissipated across the resistance & hence efficiency of system is reduced

Q Starting & Runing characteritis of DC Motor.

Characterictics of DC Motor.

The performance of DC motor under different operating condition is obtained by foll characteritics

1) Torque vs armature current characteristics. (starting chara)
2) speed vs armature current charact
3) speed vs torque characteristics (Runing)

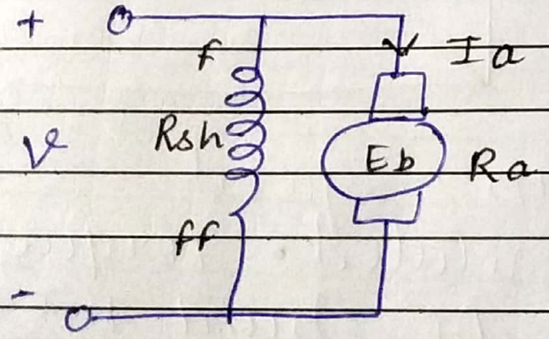
1) DC Motor

DC shunt Mr

DC series Mr

Compound Mr

(A) Characteritics of DC shunt Motor



$$N \propto \frac{V_t - I_a R_a}{\phi}$$

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

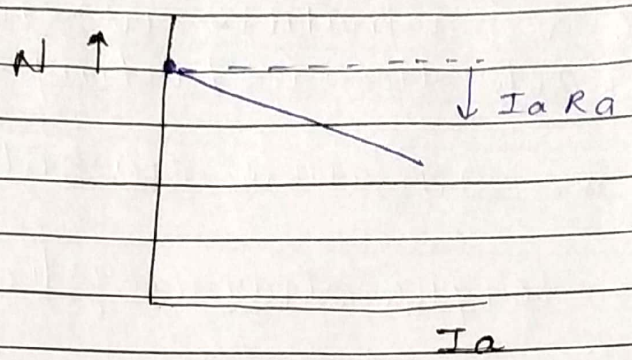
$E_b \propto \phi$. or $N = \frac{E_b}{\phi}$.

Q = constant as supply vtg is applied across field wdg

$\therefore$ $N \propto V_t - I_a R_a$

as Ia ↑ses N ↓.

a) Speed vs Ia



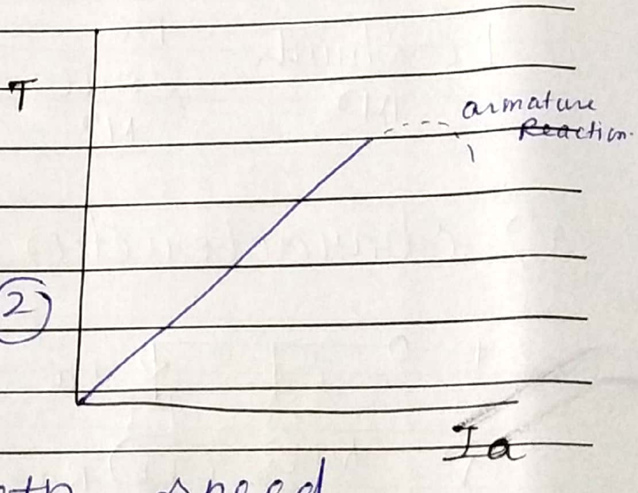
Ia = 0
N = Vt.

Ia↑ N↓

b) Torque vs Ia

$T \propto Q I_a.$

$T \propto I_a$ —①



$N \propto V_t - I_a R_a$

$N \propto V_t - T R_a$ —②

from above eqn.
the relation betn speed & torque can be related. Torque armature current of DC shunt mr is a straight line

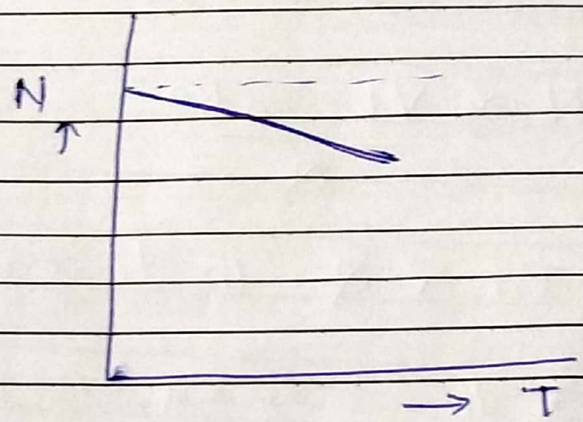
This curve shows that the m/c speed is fairly constant from no load to full load. This type of speed - torque characteristics is generally reffered as shunt characteristis

c] Speed vs torque char (N-T)

$N \propto V_t - I_a R_a$ ①

$T \propto \phi I_a$

$T \propto I_a$ ②

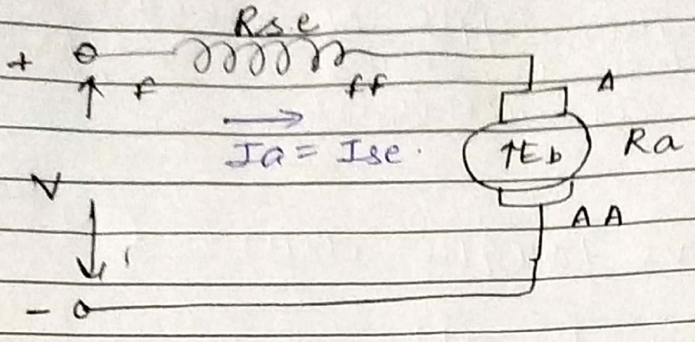


$N \propto V_t - T R_a$

$T = 0$ $N \uparrow$

$T \uparrow$ $N \downarrow$

ⓒ characteristics of DC series Motor



$I_a = I_{se}$

① N - Ia characteristics

$N \propto \frac{V_t - I_a R_a}{\phi}$

$T \propto \phi I_a$

$\phi \propto I_{se}$

$I_a \propto \phi$ in dc series m/c

$I_{se} \propto I_a$

$I_a \downarrow$ $I_a R_a$ = neglible

$T \propto I_a^2$

$V = I_a R_{se} + I_a R_a + E_b$

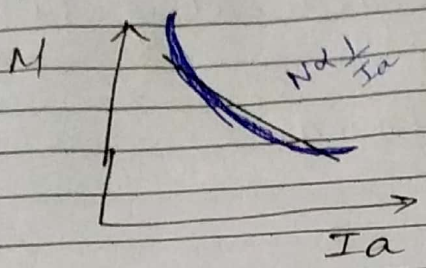
$V = I_a (R_a + R_{se}) + E_b$

$\therefore V - I_a (R_a + R_{se}) = E_b$

$\therefore N \propto \frac{E_b}{\phi} \propto \frac{E_b}{I_a}$

$N \propto \frac{1}{I_a}$

hence the speed is inversely proportional to armature current



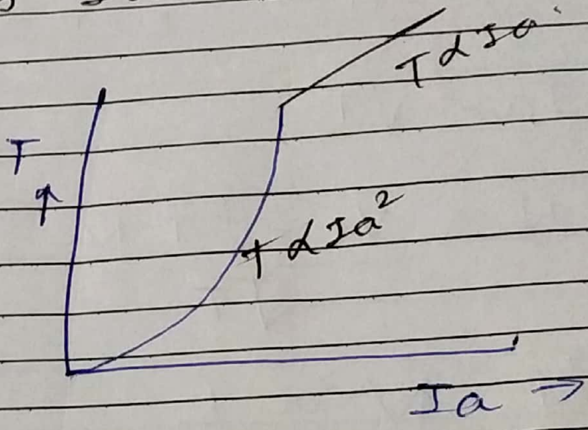
$N \propto \frac{1}{Ia}$

2) Torque versus Ia

$T \propto \phi Ia$

$Ia \propto \phi$

$T \propto Ia^2$



The field wdg of series motor being in series with the armature carries the armature current.

hence $T \propto Ia^2$

The torque under this condition is thus nearly proportional to the square of armature current & torque armature current char is parabola.

After saturation of magnetic ckt & remains practically constant
Hence $T \propto I_a$ only

3) Speed versus torque.

$$N \propto \frac{V_t - I_a R_a}{\phi}$$

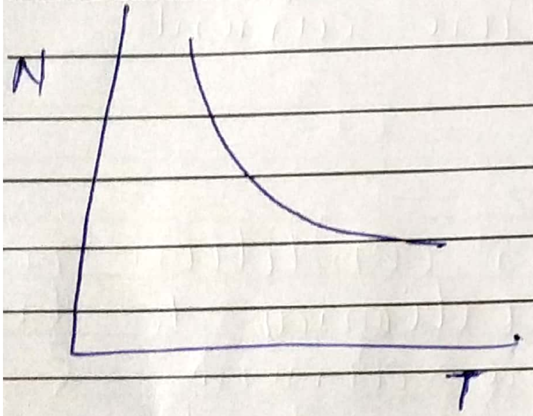
$$T \propto I_a^2 \quad , I_a \propto \phi$$

$$I_a = \sqrt{T}$$

$$\text{so } N \propto \frac{V_t - \sqrt{T}\, R_a}{\sqrt{T}}$$

~~IVF~~ $N \propto \frac{1}{\sqrt{T}}$

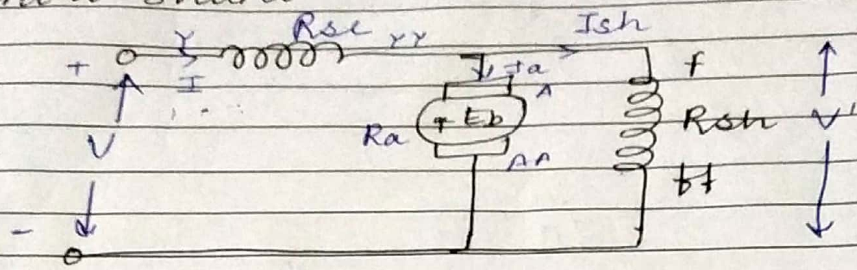
Speed torque curve is shown in fig can be easily obtained form torque-armature current & speed curve.



It shows that the speed of motor falls as torque increases.

ⓒ DC compound mr.

1) short shunt



Here the shunt field is connected across the armature & their parallel combination appears in series with series field

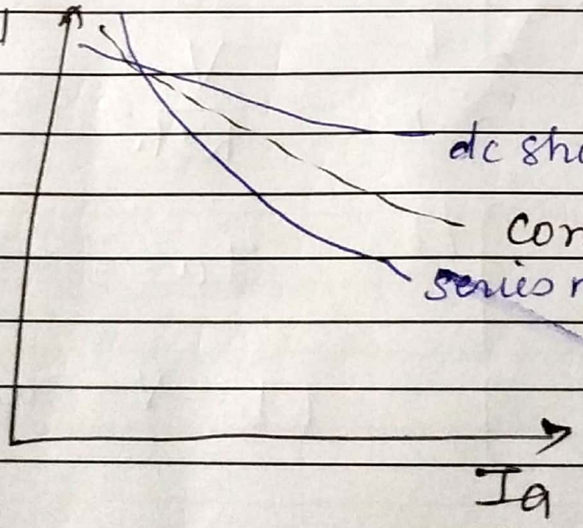
$I = I_a + I_{sh}$

$V = I R_{se} + (I_a R_a + E_b + \text{Vtg Brush})$

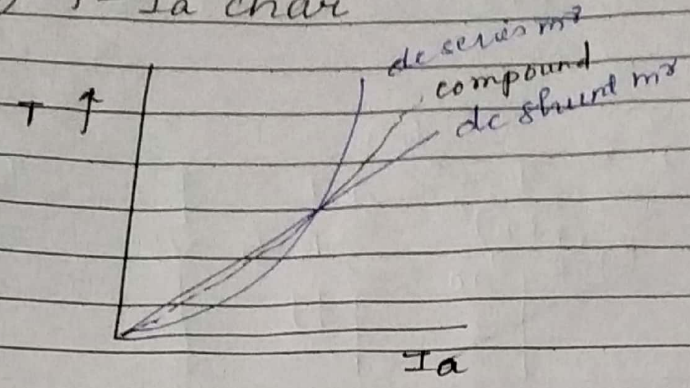
$V' = V - I R_{se}$ $\qquad V = I R_{se} + I_a R_a + E_b$

$$\boxed{V - I R_{se} - I_a R_a = E_b}$$

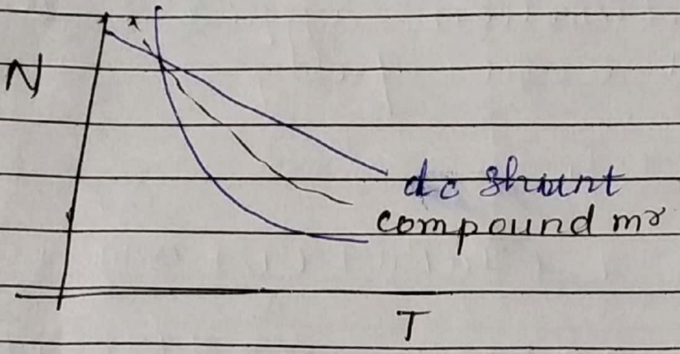
1) N(Speed) versus Ia



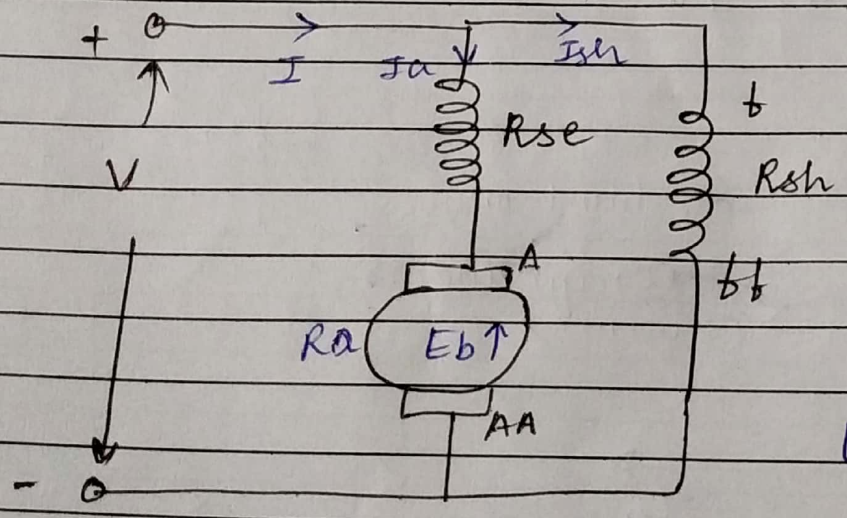
2) T – Ia char



3) N – T char



⑤ long shunt compound m/c



$$\frac{V}{R_{sh}} = I_{sh}$$

$$I_a = I - I_{sh}$$

$$E_b = V - I_a(R_a + R_{se}).$$

(*) Speed Control of DC M/s

The speed of dc motor is given by

$$N \propto \frac{E_b}{\phi} \propto \frac{V - I_a R_a}{\phi}.$$

But the resistance of armature wdg or series field wdg in case of dc series motor is small

Therefore the voltage drop $I_a R_a$ or $I_a(R_a + R_s)$ across them will be negligible as compared to the external supply vtg V.

Therefore the expression for speed

$$N \propto \frac{V}{\phi}.$$

From this exp we can obtain the factors affecting the speed of dc motor.

1) Speed is inversely proportional to flux ϕ.

2) Speed is directly proportional to applied voltage V.

3) So by varying one of the parameter, it is possible to change the speed of dc M^r.

Speed Control Method

- Flux Control
  - (change the flux by changing field current)
- Rheostati Control (Armature Resistance control)
  - (change the armature path resistance which in turn the change the armature vtg)
- voltage control.
  - (change supply voltage V.)

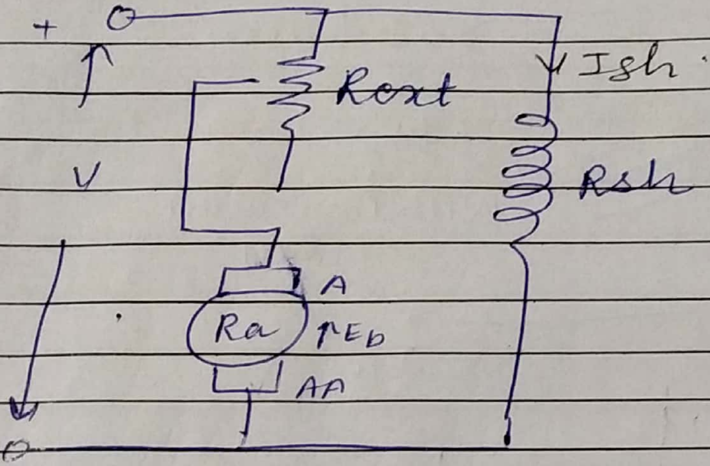
1) Armature resistance Control
OR
Armature voltage control.

In this method the vtg applied across the armature of DC shunt motor is changed to change its speed.

In this we can external resistance Rext in series with armature ckt. which will give variable resistance & field wdg is constant.

$$\frac{V_t - I_a(R_a + R_e)}{K\phi} = N$$

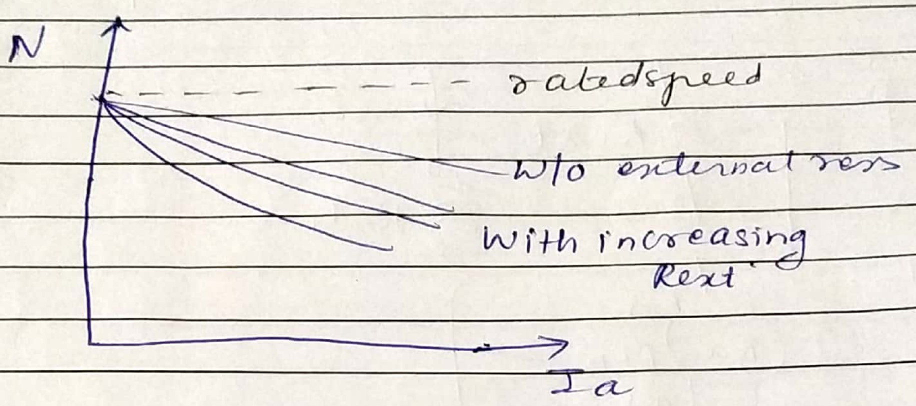
$R_e \uparrow \quad N \downarrow$.



Since the supply vtg is normally constant, the vtg applied across the armature is changed by simply connecting a variable resistance (Rext) called controlled in series with the armature.

$$\text{as } N \propto \frac{E_b}{\phi} \propto \frac{V - I_a R_a}{\phi}$$

As this external resistance (Rext) is increase the vtg applied across the armature decreases & the speed fall. By changing the value of resistance different motor speed can be obtained



Advantages:

1) For small m/c this method is suitable.

2) Simple method to obtain speed control below normal value.

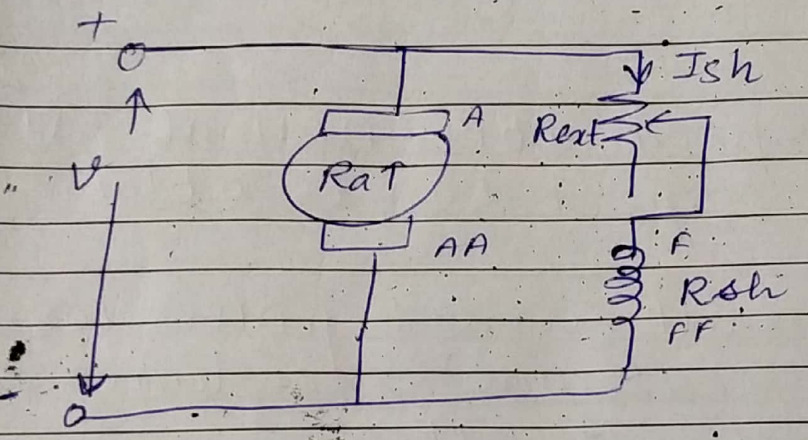
Disadvantage: 1) It is not used widely bcoz power is lost in External resistance.

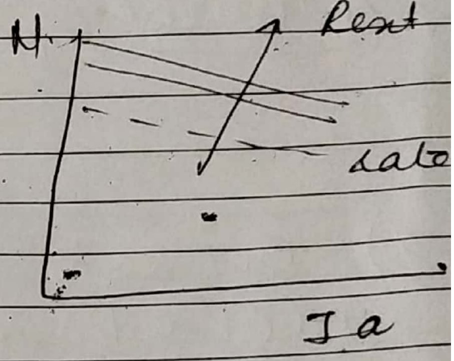
2) This method cannot give speed above normal as controller can only decreases the armature Vtg

3) This method need costly controller with proper heat dissipation arrangement

2) Flux Control Method

1) Rheostatic Control method





$Re \uparrow$ $\quad N \propto \frac{E_b}{\phi}$

$I_f \downarrow$ $\quad N \propto \frac{1}{\phi}$, $\quad \phi \propto I_{sh}$

$i_f \downarrow \; \phi \downarrow$ $\quad N \propto \frac{1}{I_{sh}}$

$\phi \downarrow N \uparrow$

the large variation in speed can be obtained by changing the flux of the DC m8.

The flux depends upon the value of field current, a variable resistance (Rext) k/as field regulator. which is connected in series with the field wdg of a DC shunt m/c as shown in fig.

When this Rext is increased, the field current & flux are reduced therefore the speed increases & vice-versa.

Advantage

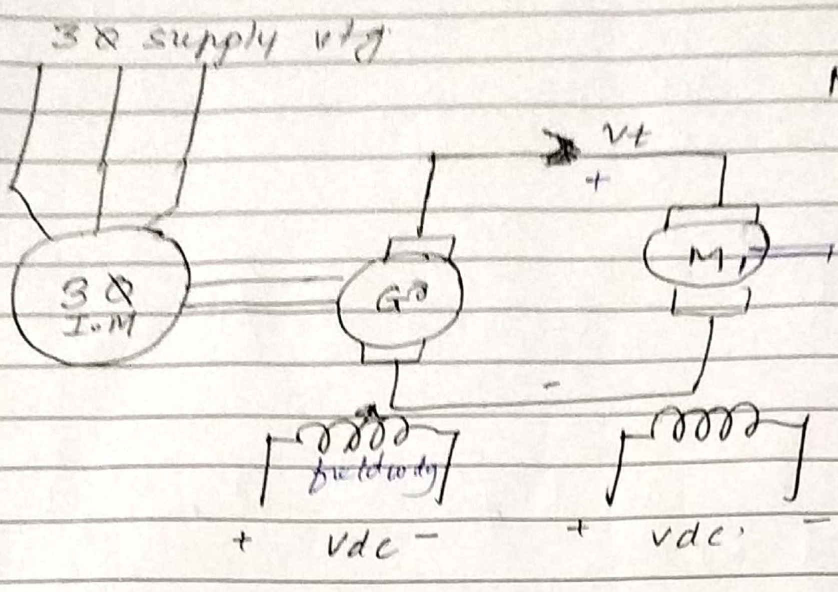
1) Speed above normal rated speed can be obtained

2) Bcoz of small current power loss involved in external resistance is comparatively small.

Disadvantage: 1) This method cannot give speed below normal value

3) Armature voltage control

✓1) ward leonard drive system



$N = \frac{V_t - I_a R_a}{\phi}$

$E_g = V_t + I_a R_a$

$E_g \uparrow \quad V_t \uparrow$

Fig show the complete scheme used in ward leonard system.

M1 is the motor whose speed is to be controlled. this method involves using a motor-generator (M-
Set.

This method is best suited for steel rolling mills, paper m/c, elevators etc. this method is k/as ward leonard system.

By changing field wdg of genr we can ctrl genr voltage.

$$E_g = V_t + I_a R_a$$

$$E_g \uparrow \quad V_t \uparrow$$

Advantages: 1) we can speed in wide range

2) The direction of mr can be changed by reversing the genr field current

Disadvant

1) It is costly as it require genr & motor set

Numerical

1) A 200 v, 10.5 A, 2000 rpm shunt motor has the arm & field resis of 0.5 & 400Ω resp It drives a load whose torque is constant at rated motor torque. Calculate motor speed if the source vtg drops to 175v

⇒

given: $I_{a_1} = 10.5 A$ $V = 200 v$ $Ra = 0.5 \Omega$

$N_1 = 2000 rpm.$ $Rsh = 400 \Omega$

Let flux at 200v be ϕ_1

at 175v be ϕ_2

$$\therefore \phi_2 = \frac{175 \phi_1}{200}$$

$$\phi_2 = 0.875 \phi_1$$

As load torque is constant.

$$I_{a_1} \phi_1 = I_{a_2} \phi_2$$

$$\therefore I_{a_2} = \frac{\phi_1}{\phi_2} I_{a_1}$$

$$= \frac{\phi_1}{0.875 \phi_1} \times 10.5$$

$$\boxed{I_{a_2} = 11.4 \text{ Amp}}$$

$E_{b1} = V_1 - I_{a1} R_a$

$= 200 - 10.5 (0.5)$

$= 195 v.$

$E_{b2} - V_2 - I_{a2} R_a$

$- 175 - 11.4 (0.5)$

$E_{b2} = 169.3 v$

$E_b \propto Q N$

$\frac{E_{b1}}{E_{b2}} - \frac{Q_1}{Q_2} \times \frac{N_1}{N_2}$

$N_2 = \frac{E_{b2}}{E_{b1}} \cdot \frac{Q_1}{Q_2} \times N_1$

$= \frac{169.3}{195} \times \frac{Q_1}{0.875 Q_1} \times 2000$

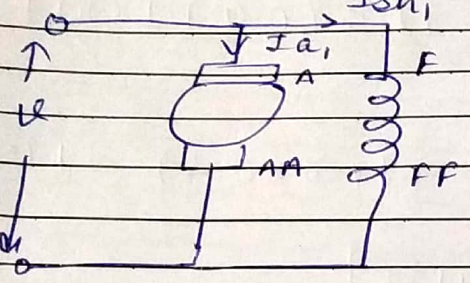
$N_2 = 1984.5$ Rpm

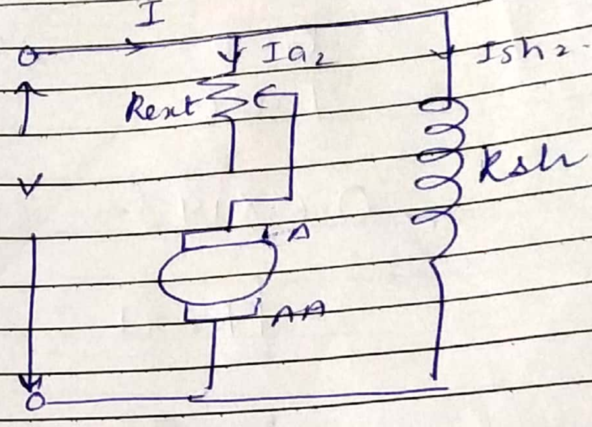
ject:

Name of Faculty:

F1 Q A 200V DC shunt m/r running at 1000 rpm takes a arm. current of 17.5 amp. It is required to reduce the speed of 600 rpm what must be the value of resistance to be inserted in series with armature ckt if the orginal value of armature resistance is 0.4 Ω take armature current to be constant during this process

⇒





$N_1 = 1000$ rpm

$I_{a_1} = 17.5$ Amp

$R_a = 0.4\,\Omega$

$V = 200$ V

$N_2 = 600$ rpm

$R_{ex} = ?$

$E_{b_1} = V - I_{a_1} R_a$

$E_{b_2} = V - I_{a_2}(R_a + R_{ext})$

$= 200 - 17.5(0.4)$

$\boxed{E_{b_1} = 193\,V}$

$E_{b_1} \propto \frac{N_1}{\phi_1}$

$E_{b_2} = \frac{N_2}{\phi_2}$

$\frac{N_2}{N_1} = \frac{E_{b_2}\ \phi_1}{E_{b_1}\ \phi_2}$

In case of dc m/c

$$\frac{N_2}{N_1} = \frac{E_{b1}}{E_{b2}} \times \frac{\phi_2}{\phi_1}$$

$$\phi_1 \propto \phi_2$$

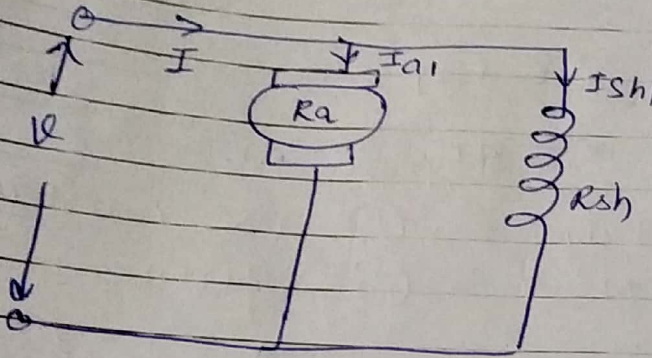
$$\frac{N_2}{N_1} = \frac{E_{b1}}{E_{b2}}$$

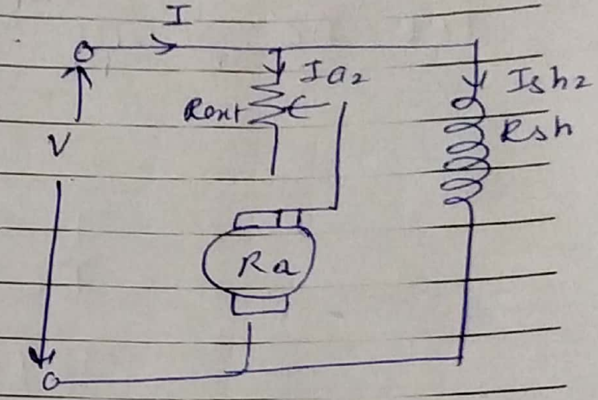
$$\frac{600}{1000} = \frac{200 - 17.5(0.4 + R_{ext})}{193}$$

$$0.6 \times 193 = 200 - (17.5 \times 0.4) - 17.5\,R_{ext}$$

$$\boxed{R_{ext} = 4.411\Omega}$$

Q A 400v, 20Hp DC shunt m/c takes 800 a current of 44 A at a speed of 1000 Rpm Calculate the value of resistance to be connected in series with armature to reduce the speed of 800 Rpm. The load torque proportional to square of speed. The shunt wdg of resistance of 200Ω & neglect the losses of armature reactance.





$V = 400V$

20Hp

$I_{a1} = 44 A$

$N_1 = 1000 Rpm$

$R_{ext} = ?$

$N_2 = 800 Rpm$

$T \propto N^2$

$R_{sh} = 200 \Omega$

$I_a R_a = $ Negligble

$I_{a1} = I - I_{sh1}$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{400}{200} = 2 \text{ Amp}$$

$I_{a1} = 44 - 2 = 42$ Amp

Motor Rating = $E_{b1} I_{a1}$

$20 Hp = E_{b1} \cdot I_{a1}$

$\cancel{10^3} \times 20 \times 746 = E_{b1} \times 42$

$E_{b1} = 355.2 V$

$E_{b1} = V - I_{a1} R_a$

$355.2 = 400 - 42 \times R_a$

$R_a = 1.066 \Omega$

for DC shunt

$T_1 \propto \phi I_{a1}$

$\phi \cancel{\propto I_{a1}}$

$T_1 \propto I_{a1}$ — ① (ϕ = constant)

$T_1 \propto N^2$ — ② given

$I_{a1} \propto N^2$

$$\frac{I_{a1}}{I_{a2}} = \left(\frac{N_1}{N_2}\right)^2$$

$$\frac{42}{I_{a2}} = \left(\frac{10\cancel{0}\cancel{0}}{8\cancel{0}\cancel{0}}\right)^2$$

$$\frac{42}{I_{a2}} = \left(\frac{10}{8}\right)^2$$

$I_{a2} = 26.88 A$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$$

$$E_{b2} = \frac{800}{1000} \times 355.2 = 284.16 V.$$

$$E_{b2} = V - I_{a2}(R_a + R_{ext})$$

$$284.16 = 400 - (26.88)(1.066 + R_{ext})$$

$$R_{ext} = 3.24 \Omega.$$

5) Q: The speed of 10 Hp, 400 V DC shunt motor is to be reduced by 20% using external resistance in a armature ckt. The field wdg current is 2A. & armature Resistance is 1Ω. Calculate the value of external resistance if the load torque remains constant & motor operates at 80% efficiency

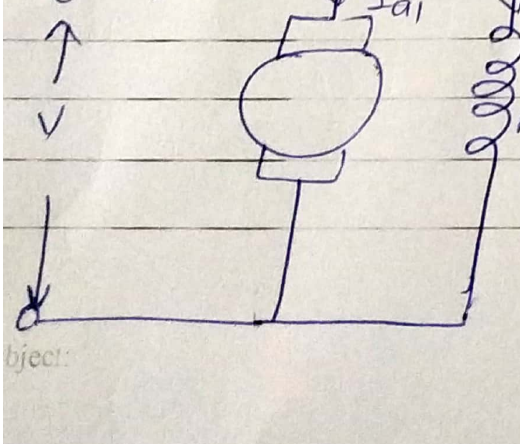
→ given: Motor Rating = 10 Hp

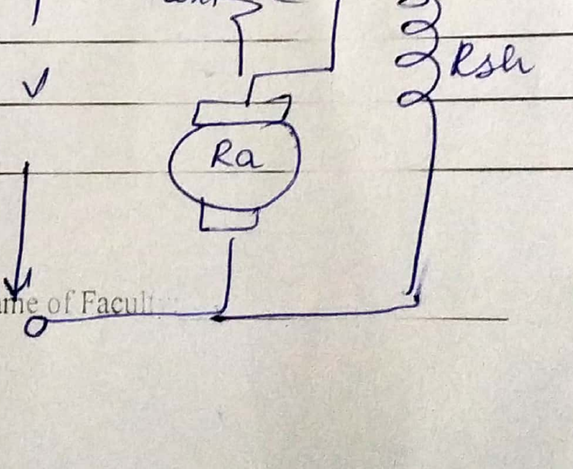
$V = 400V$

$I_{sh1} = 2$ Amp

$R_a = 1\Omega$ $\quad \eta = 80\%$

$R_{ext} = ?$





let $N_1 = N$

$N_2 = (100 - 20) N$

$= 80\% \, N$

$N_2 = 0.8 N$

$$\text{Efficiency} = \frac{\text{O/P Power}}{\text{I/P Power}}$$

$$\text{I/P Power} = \frac{10 \times 746 \times}{80/100}$$

$$\boxed{\text{I/P Power} = 9.325 \text{ ~~K~~w}}$$

$\text{I/P Power} = V \cdot I$

$9.325 \times 10^3 = 400 \times I$

$$\boxed{I = 23.31 \text{ A}}$$

$I = I_{a1} + I_{sh1}$

$I_{a1} = I - I_{sh1}$

$= 23.31 - 2$

$= 21.31$ Amp

$E_{b1} = V - I_{a1} R_{a1}$

$= 400 - 21.31 \times .1$

$= 378.69$ V.