

**Q2 (a) State and explain Faraday's laws of electromagnetic induction.**

**Answer**

Faraday gave following two laws of electromagnetic induction.

Law I: - An induced emf is established in a circuit whenever the magnetic field linking that circuit is changed.

Law II:-The magnetic of the induced emf is equal to the rate of change of the magnetic flux linking with the circuit. Stated mathematically,

$$|e| = \frac{d\phi}{dt}$$

Let us consider a loop of wire (i.e a coil of single turn) placed in a magnetic field. If the flux through the loop change from  $\phi_1$  to  $\phi_2$  during time interval  $\Delta t$ , an emf  $e$  will be produced in the loop, where

$$|e| = \frac{\phi_2 - \phi_1}{\Delta t}$$

If a coil of wire has  $N$  turns, emf will be generated in each turns by the changing magnetic flux. The emf generated in the coil will be the sum of the emfs in the separate turns. If the change in the magnetic flux is the same in each turn, then the induced emf will be given as

$$|e| = N \frac{\phi_2 - \phi_1}{\Delta t}$$

**Q2 (b) A conducting circular loop is placed in an uniform magnetic field ( $B$ )=0.020 T with its plane perpendicular to the field. Somehow, the radius of the loop starts shrinking at a constant rate of 1.0 mm/s. Find the induced emf in the loop at an instant when the radius is 2 cm.**

**Answer**

Let the radius be  $r$  at a time  $t$ . The of the magnetic field at the instant is  $Q = \pi r^2 B \frac{dr}{dt}$

Here,  $r = 2 \text{ cm} = 2 \times 10^{-2} \text{ m} = 0.02 \text{ m}$   $B = 0.02 \text{ T}$

$$\frac{dr}{dt} = 1 \text{ mm/sec} = 0.001 \text{ m/sec.}$$

$$\begin{aligned} \therefore e &= \frac{dQ}{dt} = 2\pi r B \frac{dr}{dt} = 2\pi \times 2 \times 10^{-2} \times 0.02 \times 1 \times 10^{-3} \\ &= 2.5 \times 10^{-6} \text{ V} \end{aligned}$$

**Q3 (a) Explain the principle of working of transformer.**

**Answer**

A transformer operates on the principle of mutual induction between two coils. These are linked by a common magnetic flux. The two coils or winding are electrically separate but magnetically linked. This link is a low reluctance path called core of the transformer. One winding is called primary and has  $N_1$  turns. It is energized by sinusoidal voltage  $V_1$ . The second winding is called secondary and has  $N_2$  turns.

This winding funds the load. The alternating current in the primary winding sets up an alternating flux  $\phi$  in the core. The secondary winding is also linked by most of this flux  $\phi$ .

The emfs are induced in the two windings due to this alternating flux in the core. Figure below shows the transformer circuit symbol.

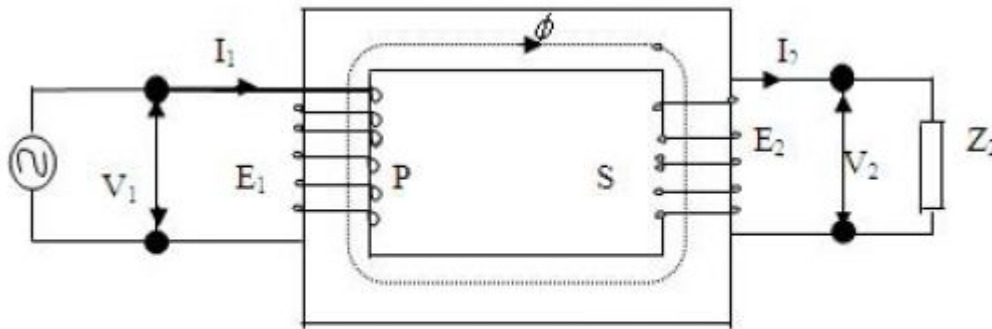


Figure 10.1

The two parallel lines denote the iron core. By having different ratios the number of turns of the two winding, the power at lower or at higher voltage can be obtained. When the number of turns in the secondary winding is less than

That is the primary winding; it is called a step down transformer. On the other hand, if the number of turns in the secondary winding is higher, it called a step up transformer

**Q3 (b) A 230/110 V, single-phase transformer takes an input of 350 volt-amperes at no load while working at rated voltage. The core loss is 100 W. Find the iron-loss component of no-load current, the magnetizing component of no-load current and the no-load power factor.**

**Answer**

$$V_0 I_0 = 350VA$$

Given

$$I_0 = \frac{350}{230} = 1.52A$$

The core loss (or input power at no load) is given by

$$P_i = V_0 I_0 \cos \phi_0 = 100W$$

Therefore, the power factor at no load is given as

$$\cos \phi_0 = \frac{P_i}{V_0 I_0} = \frac{110}{350} = 0.314$$

The iron-loss component of no load current is given as

$$I_w = I_0 \cos \phi_0 = 1.52 \times 0.314 = 0.478 \text{ A}$$

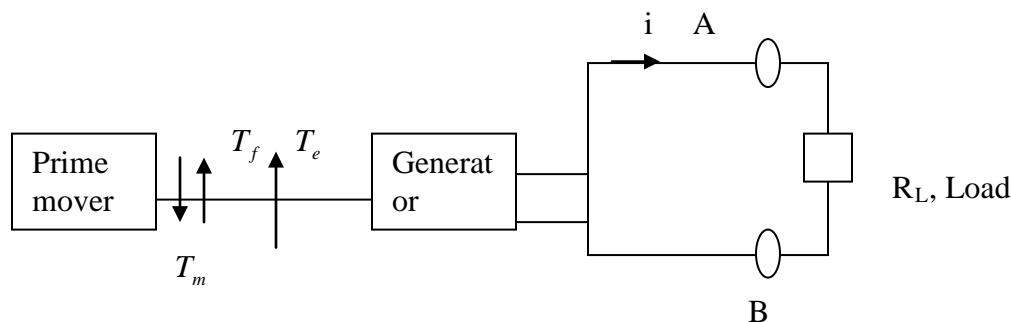
The magnetizing component of No-load current is given as

$$I_m = \sqrt{I_0^2 - I_w^2} = \sqrt{(1.52)^2 - (0.478)^2} = 1.44 \text{ A}$$

**Q4 (a) Draw and explain the power flow diagram for a DC generator.**

**Answer**

Consider a generator whose shaft is rotated by a prime-mover. The prime mover applies a mechanical torque  $T_m$  on the rotor of the generator. An emf  $e$  is induced in the coil. The coil terminals AB are connected to an electronic load  $R_L$  so that current  $i$  flows.



The current-carrying coil experiences an electromagnetic torque  $T_e$ . This is a reaction torque and it opposes the applied torque. Thus the applied torque  $T_m$  overcomes  $T_f$  as well as  $T_e$  as shown in figure above. We have

$$T_m = T_f + T_e$$

Multiplying both sides by  $\omega$  we get

$$T_m \omega = T_f \omega + T_e \omega$$

This means out of the total mechanical power  $T_m \omega$  supplied by the prime mover, only  $T_e \omega$

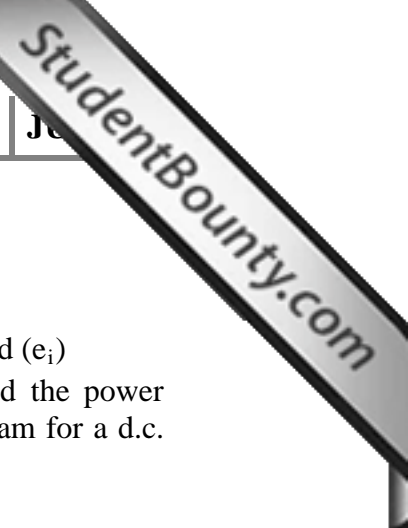
is converted into  $T_f \omega$  is wasted in frictional loss.

Now, consider the output side, If  $r$  is the resistance of the coil and  $R_L$  is the load resistance, the current through the circuit is given as

$$i = \frac{e}{r + R_L} \text{ or}$$

$$e = ir + iR_L$$

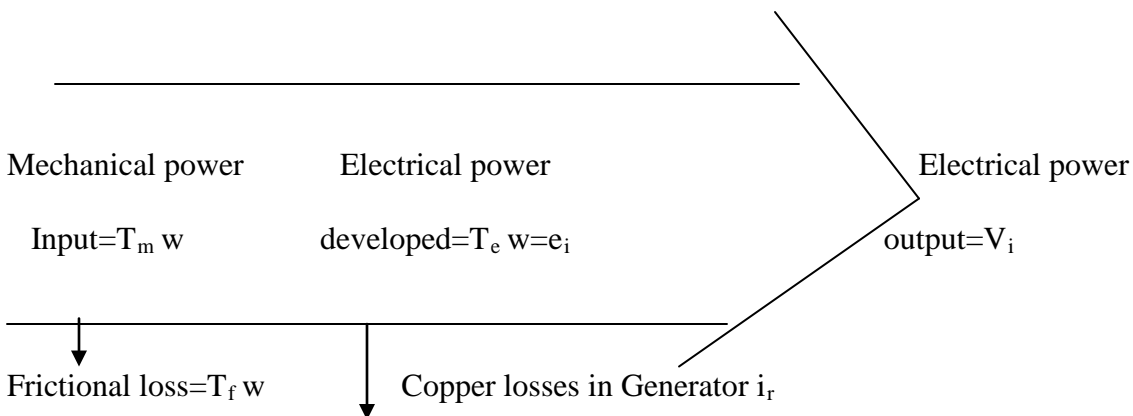
Multiplying both sides by  $I$ ...we get



$$e_i = i^2 r + i^2 R_L$$

$$\Rightarrow ei = i^2 r + i v$$

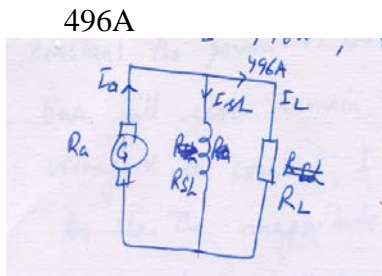
Where  $V=i R_L$  is the terminal voltage. This means electrical power developed ( $e_i$ ) Is equal to the sum of the power lost in resistance of the coil ( $I^2 r$ ) and the power delivered to the electrical load ( $v_i$ ). Thus, the power flow diagram for a d.c. generator can be drawn as follows.



**Q4 (b) A shunt wound DC generator delivers 496 A at 440 V to a load. The resistance of the shunt field coil is  $110\Omega$  and that of the armature winding is  $0.02\Omega$ . Calculate the emf induced in the armature winding.**

**Answer**

Given  $I_L = 496A, V = 440V, R_{sh} = 110\Omega, R_a = 0.02\Omega$



$$I_{sh} = V/R_{sh} = 440/110 = 4A$$

$$I_a = I_L + I_{sh} = 4 + 496 = 500A$$

$\therefore$  The generated emf

$$E = V + I_a R_a = 440 + 500 \times 0.02 = 450V$$

**Q5 Discuss in detail the operation of a synchronous motor at constant load with variable excitation.**

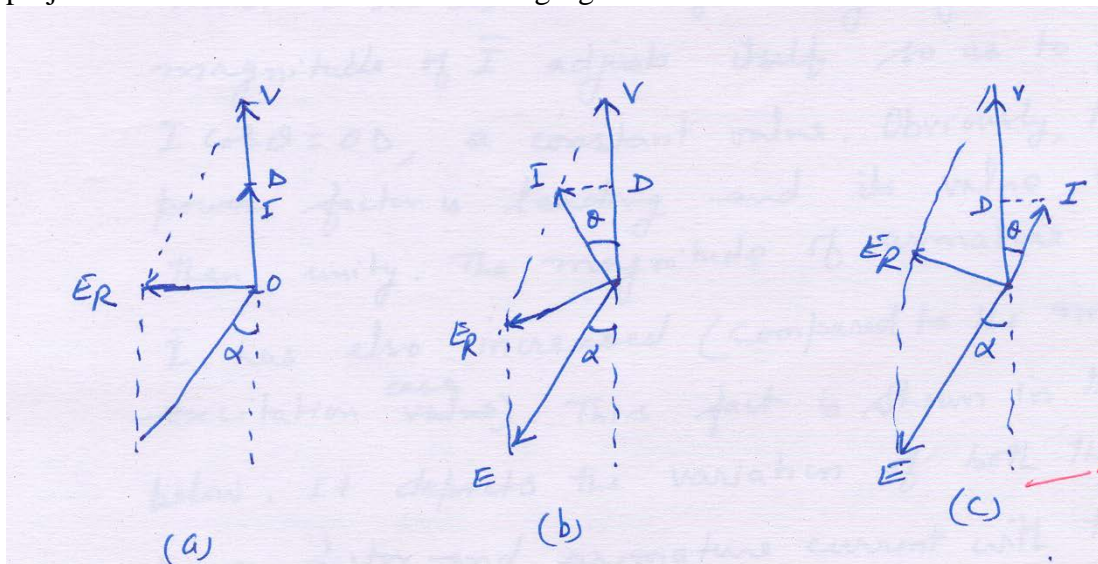
**Answer**

In a synchronous motor the rotor windings are supplied dc current. The rotor poles produce the magnetic field. The current  $I_f$ , going to the field winding on the rotor is called excitation current. When we change the excitation  $I_f$ , the magnitude of the induced emf  $E$  in the stator winding changes.

Suppose that a synchronous motor is running and is supplying power to a fixed mechanical load. Whatever we do to the excitation  $I_f$ , so long as the load on the motor remains constant, the torque angle  $\alpha$  (i.e the angle of lag of induced emf  $E$  from the axis of the phasor  $V$ ) too remains constant.

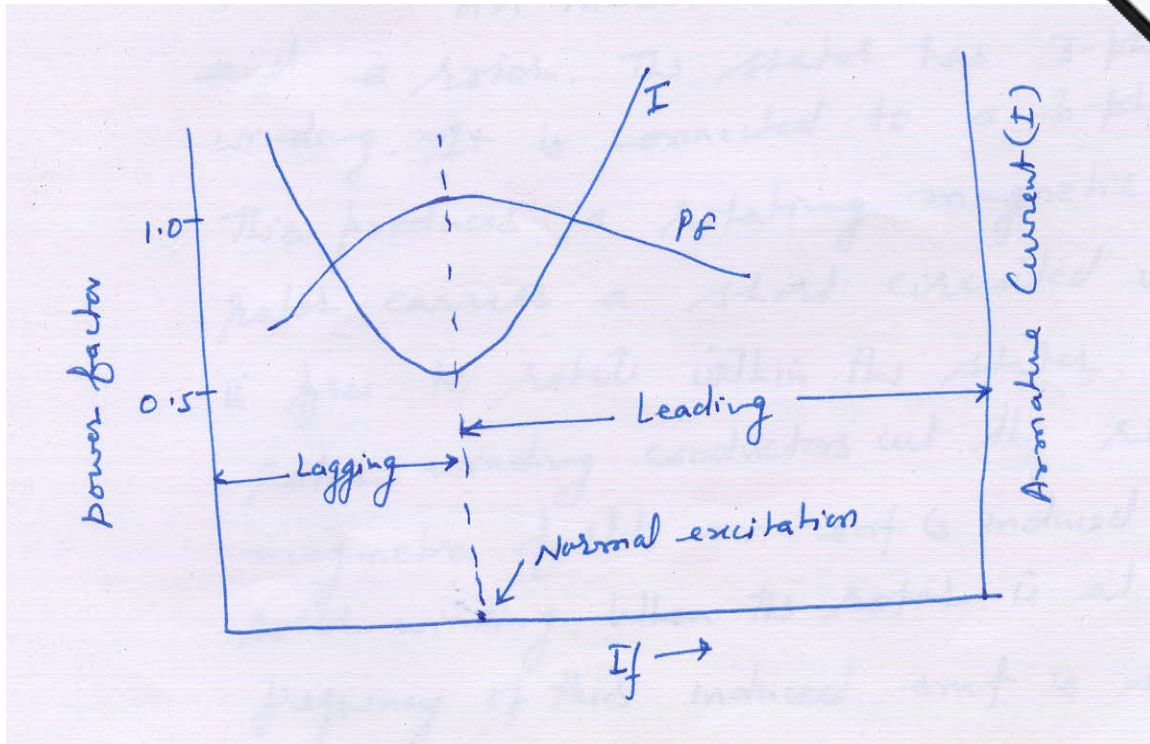
Further, if the mechanical load on the motor constant, the power  $VI \cos \phi$  drawn the bus bar will also remain constant. As the bus bar voltage  $V$  is constant,  $I \cos \phi$  also remains constant.

The magnitude of  $I \cos \phi$  is simply the projection of phase  $I$  on the axis of phasor  $V$ . the projection is shown as  $6D$  in the following figure



Let us now examine, how the change in excitation of a synchronous motor at constant load affects the armature current  $I$  and the power factors  $\cos \phi$ . There is some definite value of excitation for which the situation will be as shown in fig (a) above. The resultant voltage  $E_R$  of the induced emf  $E$  and the applied voltage  $V$  is such that the current  $I$  is in phase with voltage  $V$ . this means that the power factor is unity. the excitation corresponding to the unity power factor current drawn by the motor is called normal excitation (fig a)

Now suppose that we give an excitation more than normal excitation. This is a case of over excitation. The induced emf  $E$  will now have larger magnitude (fig. b). we find that now the resultant the voltage  $E_R$  is such that the current  $I$  leads the voltage  $V$  by angle  $\phi$ . the magnitude of  $I$  adjust itself so as to give  $I \cos \phi = \phi D$ , a constant value. obviously, the power factor is leading and its value is less than unity. The magnitude of armature current  $I$  as also increased (compared to the normal excitation case). This fact is shown in that fig. below. It depicts the variation of both the power factors and armature current with the variation in excitation  $I_f$ .



Next, let us consider what happens when the machine is under excited. As shown in fig (c), the induced emf  $E_R$  will now have smaller magnitude.

The resultant voltage  $E_R$  is such as to make the armature current  $I$  lagging the voltage  $V$  by some angle  $\phi$ . However,  $I \cos \phi = \phi D$  still remains the same. The power factor is lagging and has a value less than unity. The magnitude of  $I$  will again be more than that in the normal excitation case. This is shown in the 2<sup>nd</sup> figure. The shape of the curve  $I$  versus  $i_f$  is similar to the letter V and hence characteristic is often called V-curve of the synchronous motor.

**Q6 (a) Explain why a three-phase induction motor rotates always with a speed less than the synchronous speed.**

**Answer**

An induction motor has a stator and a rotor. The stator has a 3-phase winding. It is connected to a 3-phase supply which produces a rotating magnetic field and is free to rotate within the stator. When the rotor winding conducts in the rotating magnetic field, the rotor carries a short-circuited winding and is free to rotate within the stator. When the rotor winding conductors cut the rotating magnetic field in the stator winding, an emf is induced in the rotor winding. When the rotor is at rest, the frequency of this induced emf is the same as the supply frequency.

As the rotor winding circuit is short-circuited at the two ends, a current flows through the rotor winding. The current-carrying conductors on the rotor interact with the rotating magnetic field. This interaction produces a torque which causes the rotor to rotate in the same direction as that of the magnetic field.

Once the rotor starts rotating, the relative motion between the stator rotating magnetic field and the rotor-conductors is reduced. Consequently, the induced emf, the current and its frequency are all reduced.

If the motor shaft is not loaded, the machine has to rotate to meet the mechanical losses. The rotor speed is very close to the synchronous speed.

However, the rotor can never be the same as the synchronous speed. If it is so, the induced emf in the rotor – winding would become zero and then would be no torque produced. Hence the rotor speed always remains slightly less than the synchronous speed.

**Q6 (b) A 6-pole induction motor is fed from 50 Hz supply. If the frequency of a rotor emf at full load is 2 Hz, find the full-load slip and speed.**

**Answer**

*Given*

$$f = 50\text{Hz}, P = 6, f_r = 2\text{Hz}$$

*since*

$$f_r = f \cdot s$$

$$s = \frac{f_r}{f} = \frac{2}{50} = .04 = 4\%$$

*the synchronous speed  $N_s$*

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000\text{rpm}$$

*full load speed*

$$N = N_s(1 - s) = 100(1 - 0.04) = 960\text{rpm}$$

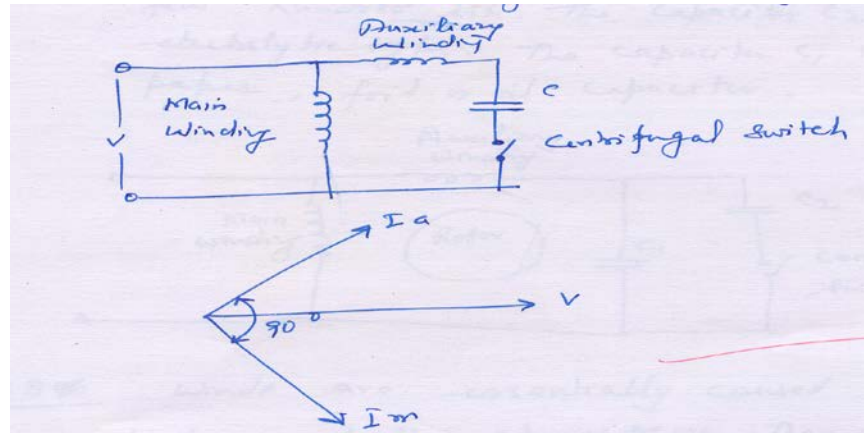
**Q7 (a) Explain the principle of operation of a capacitor start single-phase AC motor.**

**Answer**

Capacitor – start Motor

Basically, it is a split phase motor having the main and auxiliary windings space displaced by  $90^\circ$ . The time displacement between the currents of main and auxiliary windings is achieved by connecting a capacitor in series with

Auxiliary winding. the current  $I_a$  in auxiliary winding leads the applied voltage  $V$  by some angle. By selecting capacitor of proper value, the auxiliary winding current  $I_a$  can be made to lead the main winding current  $I_m$  by about  $90^\circ$  thus the Motor develops a much larger starting torque than that developed in a resistance – start split phase motor. Both the capacitor and auxiliary winding are designed for start time duty. The centrifugal switch disconnects then after the motor has attained about 75% rated speed. The circuit and phasor diagrams are given below

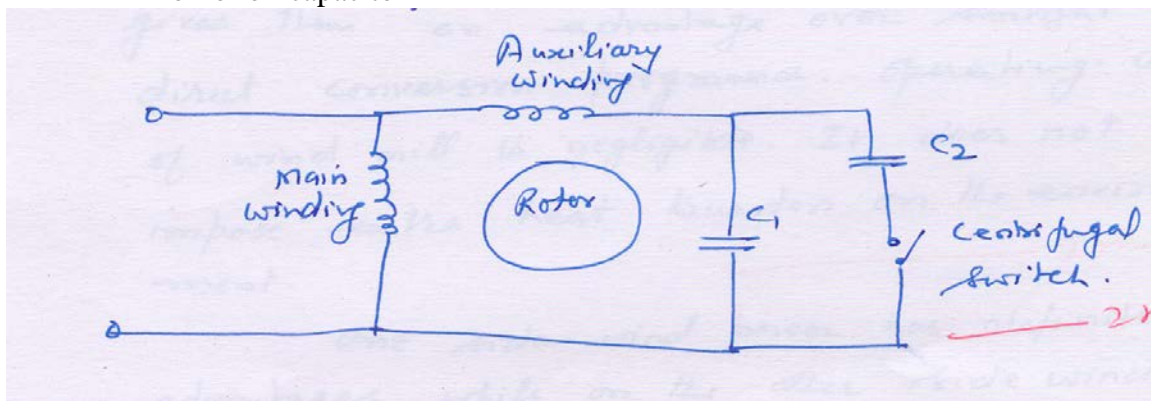


**Q7 (b) Explain the principle of operation of a capacitor-start capacitor-run single phase AC motor.**

**Answer** Capacitor – start capacitor –Run Motor

This motor has two capacitors in the auxiliary circuit as shown in the fig. below. The two capacitors  $C_1$  and  $C_2$  are connected in parallel. During starting both the capacitors are in circuit.

After the motor has picked up speed, the centrifugal switch opens and disconnects capacitor  $C_2$  from the circuit. Thus the motor behaves more like a balanced two phase motor. The two-phase operation results in better efficiency. The use of capacitor for running condition improves power factor. The capacitor  $C_1$  has a value of about a few micro F while  $C_2$  is much larger in value and is generally in the range of 50 micro F to a few hundred micro F. The capacitor  $C_2$  is of electrolytic type. The capacitor  $C_1$  is a paper foil or oil capacitor.



**Q8 (a) Discuss the advantages and limitations of utilizing wind energy for electricity generation.**

**Answer**

Winds are essentially caused by solar heating of the atmosphere. They carry enormous quantity of energy. In early days wind power has served many



countries as source of power and were called wind mills. Wind power has been used for centuries to sail vessels, pump water, and grind wheat and cone. At the of this century, around 30,000house mills capable of generating Total of 100 mW and 3000 industrial wind mills generating another 100mW were in operation in Denmark. Every year the winds provide 26000 trillion kWh of which one -third is recoverable.

Wind as a source of power is plentiful, in exhaustible, renewable and non-polluting. In page portion of the world, wind blow for 320 days in a year and this gives them an advantage over sunlight in direct conversion programmer. Operating cost of wind mill is negligible .It does not impose extra heat burden on the environment.

One side wind power has definite advantage, while on the other sides wind power has certain limitation as well .This source of power is non-steady, unreliable, wind variations in the speed and direction of winds. It makes necessary to store wind energy in some other forms during periods of high winds for use later on during calm. This energy can be stored in the form of chemical energy in rechargeable batteries, potential energy in rechargeable batteries, potential energy in high level reservoirs and mechanical energy in fly wheels etc.

Another draw back of wind power is the unwieldy size, high structural area and quite large finance requirement .also the varying speed creates problem in case of wind mills employed for electric power generation (ac output). Due to this the speed of wind mills will very resulting in fluting voltage and frequency. However methods have been devised to generate constant frequency power write varying speeds of wind mill propellers. In one of the mechanism, the pitch of the wind speed is sensed by a governor and the blade pitch is automatically adjusted to regulate the output.

**Q8 (b) Draw the block diagram representation of a thermal power generation unit. Write the function of its main components.**

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**Q9 Explain the need for energy storage. What are various methods of energy storage? Explain the compressed air storage and heat storage methods of storing energy.**

**Answer**

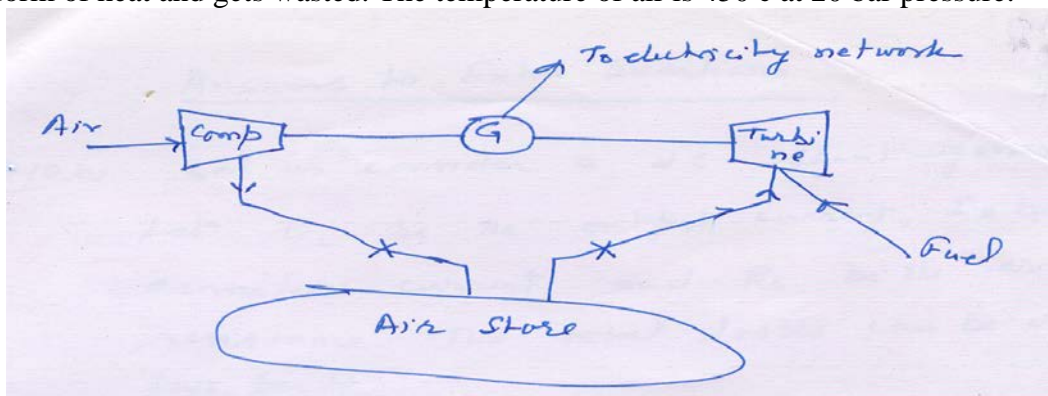
Because of tremendous differential in storage of electricity generated, transmitted and utilized. Large scale storage of energy which can be quickly converted to electrical form, can help fast changing loads this would helps fast changing loads. This would help to ease operation and make the overall system economical as large capacity need not be kept on line to take up short duration load. The operation available is the following

1. Pumped storage
2. Compressed air storage
3. Heat storage
4. Hydrogen gas storage
5. Batteries
6. Fly wheels

There compressed air storage and heat storage system are discussed.

### Compressed Air Storage

Compressed air can be stored in natural underground caverns or old mines. The energy stored equal the volume of air multiplied by pressure .At the time of need this air can be mixed gas fuel to run a gas turbine as shown in figure below . Gas fuel combustion efficiency is there by doubled compressed to normal operation .A disadvantage of this scheme in that much of the energy used in compressing air appears in form of heat and gets wasted. The temperature of air is 450 c at 20 bar pressure.



### Heat storage

No large storage of heat has been found to be feasible. Water with good specific and latent heat has been suggested .Liquid sodium is another alternative .It is used in FBRs for heat transfer. In a generating station, boilers can be kept ready on full steam for turbine to turbine to pick up fast rising load. Boiler steam when not in use can heat feed water for boilers in the station

### Text Book

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