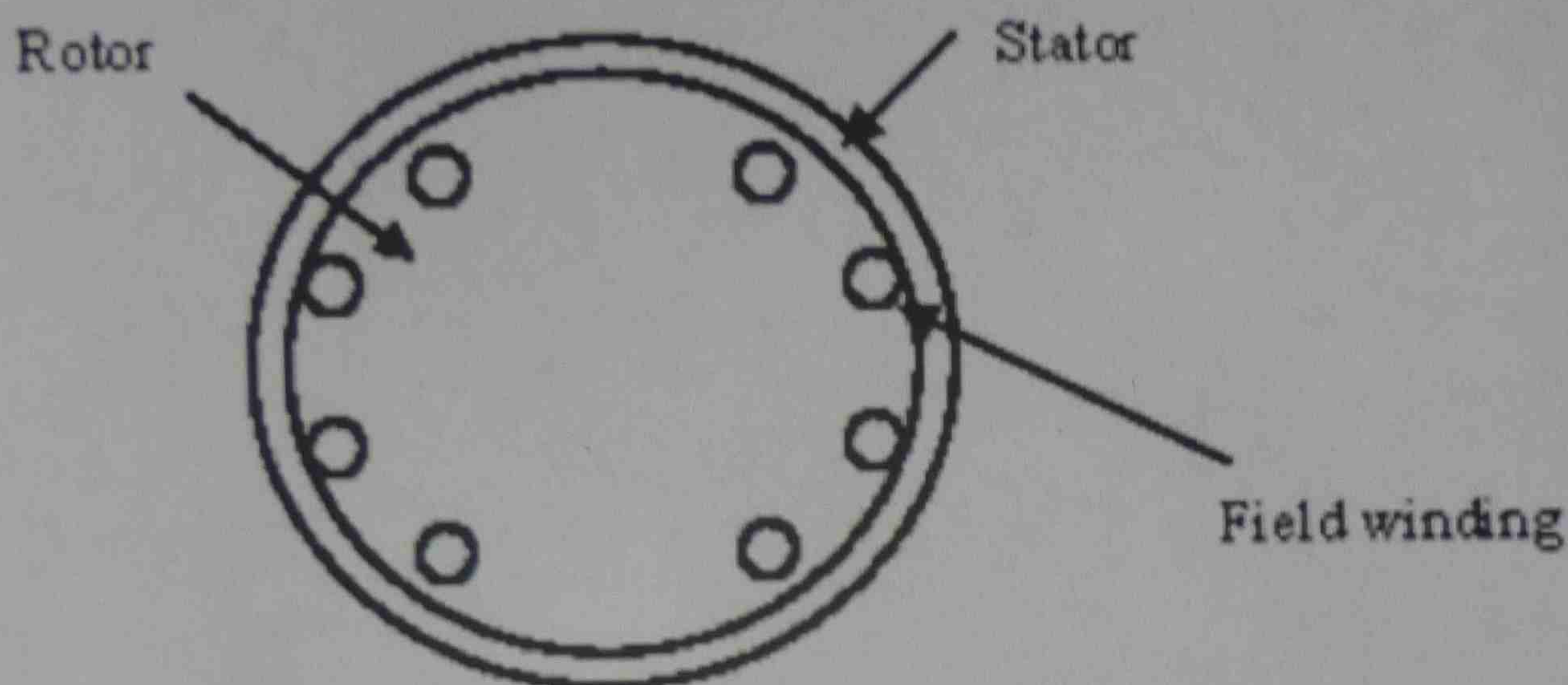


Q100. Explain cylindrical rotor machine.

A mathematical model of the three-phase, cylindrical-rotor, synchronous machine for symmetrical and asymmetrical modes of operation has been developed. This model has been represented as system of differential equations for flux linkages, angular velocity and angular position determination. The differential equations for the flux linkages of the armature windings have been expressed in phase coordinates, while the differential equations for the flux linkages of the field winding and the rotor circuits have been expressed in orthogonal coordinates (direct and quadrature axes). The skin effect in the cylindrical-rotor has been considered by representing the rotor as two parallel-connected resistive-inductive circuits. Symmetrical case followed by a steady-state operating conditions (sudden load change) and asymmetrical case in a transient operating conditions (line-to-line short circuit in the electrical power system) have been computed. The waveforms of the machine speed, electromagnetic torque, phase currents and voltages have been illustrated.



Construction of cylindrical-rotor synchronous machine

When a synchronous generator is excited with field current and is driven at a constant speed, a balanced voltage is generated in the armature winding. If a balanced load is now connected to the armature winding, a balanced armature current at the same frequency as the emf will flow. Since the frequency of generated emf is related to the rotor speed, while the speed of the armature rotating mmf is related to the frequency of the current, it follows that the armature mmf rotates synchronously with the rotor field. An increase in rotor speed results in a rise in the frequency of emf and current, while the power factor is determined by the nature of the load.

The effect of the armature mmf on the resultant field distribution is called *armature reaction*. Since the armature mmf rotates at the same speed as the main field, it produces a corresponding emf in the armature winding. For steady-state performance analysis, the per-phase equivalent circuit shown in Figure 3 is used. The effects of armature reaction and armature winding leakage are considered to produce an equivalent internal voltage drop across the synchronous reactance X_s , while the field excitation is accounted for by the open-circuit armature voltage E_f . The impedance $Z_s = (R + jX_s)$ is known as the synchronous impedance of the synchronous generator, where R is the armature resistance.

Thi Truong

G045—Induction machines

Q1. formula to calculate rotating magnetic field.

$$I_{apk} = I_m \cos 2_{.50.t}$$

Q2. Calculate the synchronous speed of a three phase induction motor having 12 poles , 60HZ.

$$N = 120 \times (f / P) \Rightarrow 120 \times (12/60) = 24 \text{ rpm}$$

N = speed in RPM, f = Applied frequency in Hz , P= number of magnetic poles

Q3. Explain the starting characteristics of squirrel cage motor.

An **AC motor** is an electric motor driven by an alternating current.

It commonly consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft that is given a torque by the rotating field.

A squirrel cage rotor is the rotating part used in the most common form of AC induction motor. An electric motor with a squirrel cage rotor is termed a **squirrel cage motor**.

The field windings in the stator of an induction motor set up a rotating magnetic field around the rotor. The relative motion between this field and the rotation of the rotor induces electric current in the conductive bars. In turn these currents lengthwise in the conductors react with the magnetic field of the motor to produce force acting at a tangent orthogonal to the rotor, resulting in torque to turn the shaft. In effect the rotor is carried around with the magnetic field but at a slightly slower rate of rotation. The difference in speed is called *slip* and increases with load.

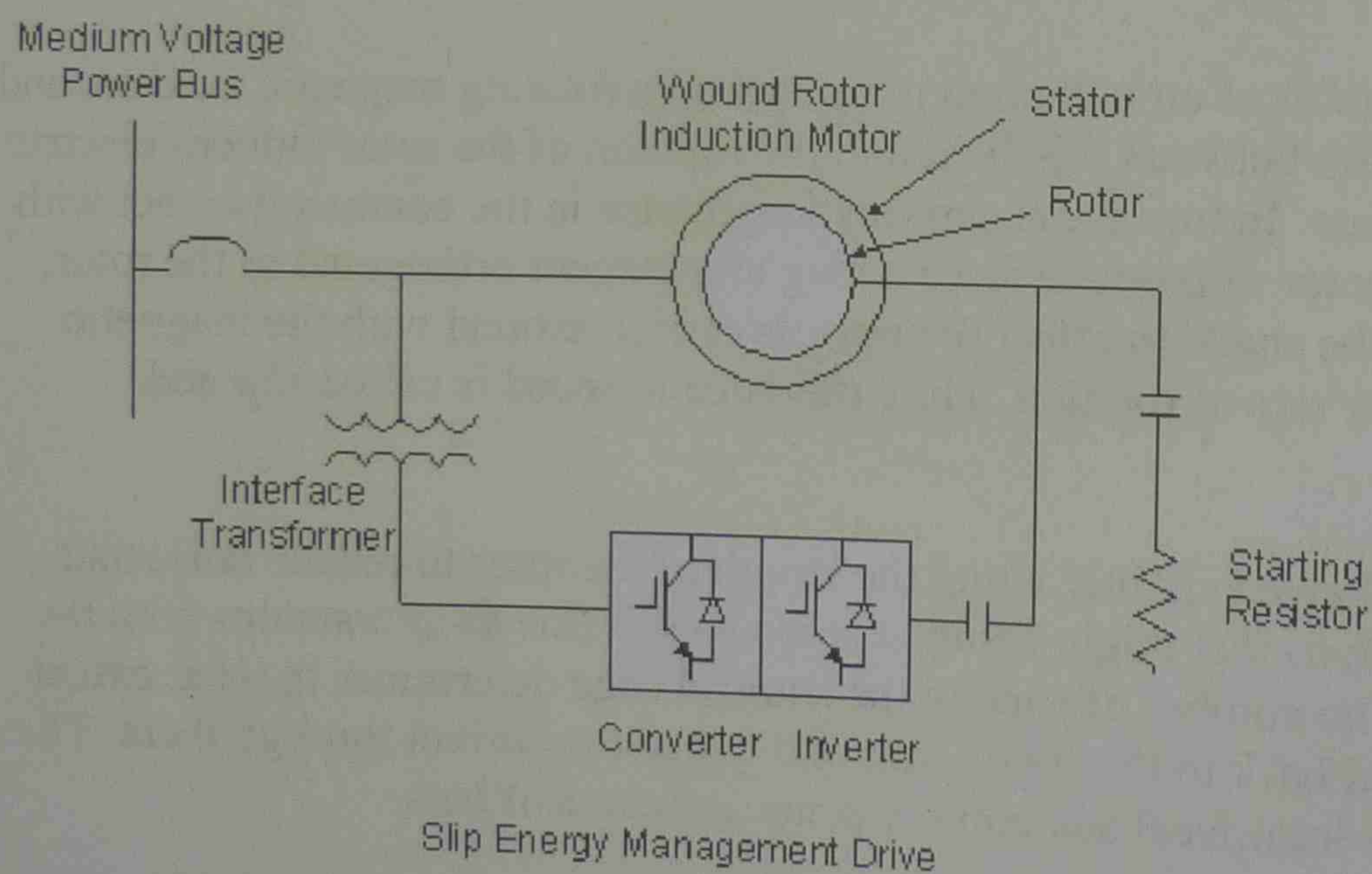
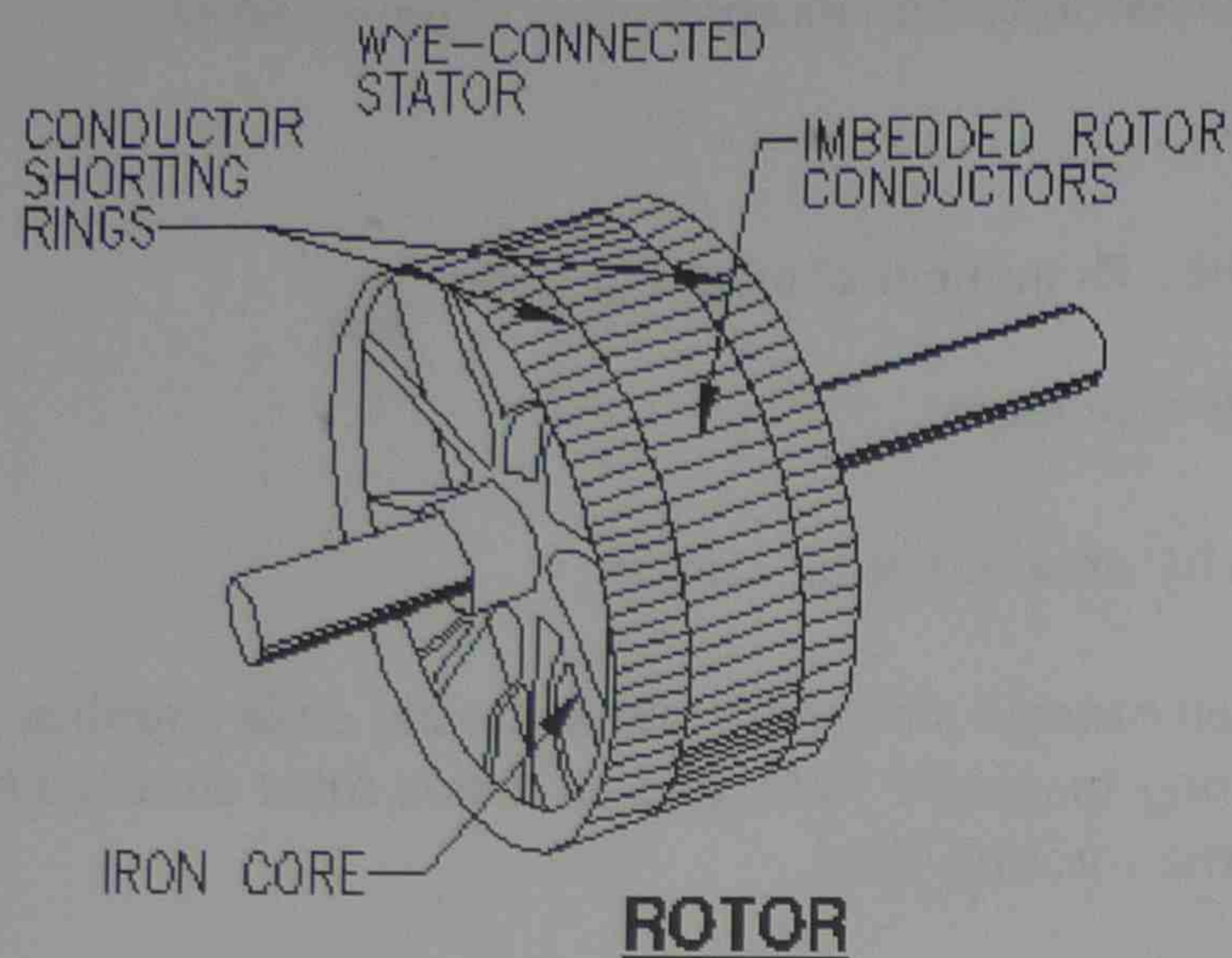
The conductors are often skewed slightly along the length of the rotor to reduce noise and smooth out torque fluctuations that might result at some speeds due to interactions with the pole pieces of the stator. The number of bars on the squirrel cage determines to what extent the induced currents are fed back to the stator coils and hence the current through them. The constructions that offer the least feedback employ prime numbers of bars.

The iron core serves to carry the magnetic field across the motor. In structure and material it is designed to minimize losses. The thin laminations, separated by varnish insulation, reduce stray circulating currents that would result in eddy current loss. The material is a low carbon but high silicon iron with several times the resistivity of pure iron, further reducing eddy-

current loss. The low carbon content makes it a magnetically soft material with low hysteresis loss.

The same basic design is used for both single-phase and three-phase motors over a wide range of sizes. Rotors for three-phase will have variations in the depth and shape of bars to suit the design classification.

Q4. Sketch the construction of squirrel cage induction motor and wound rotor motor.

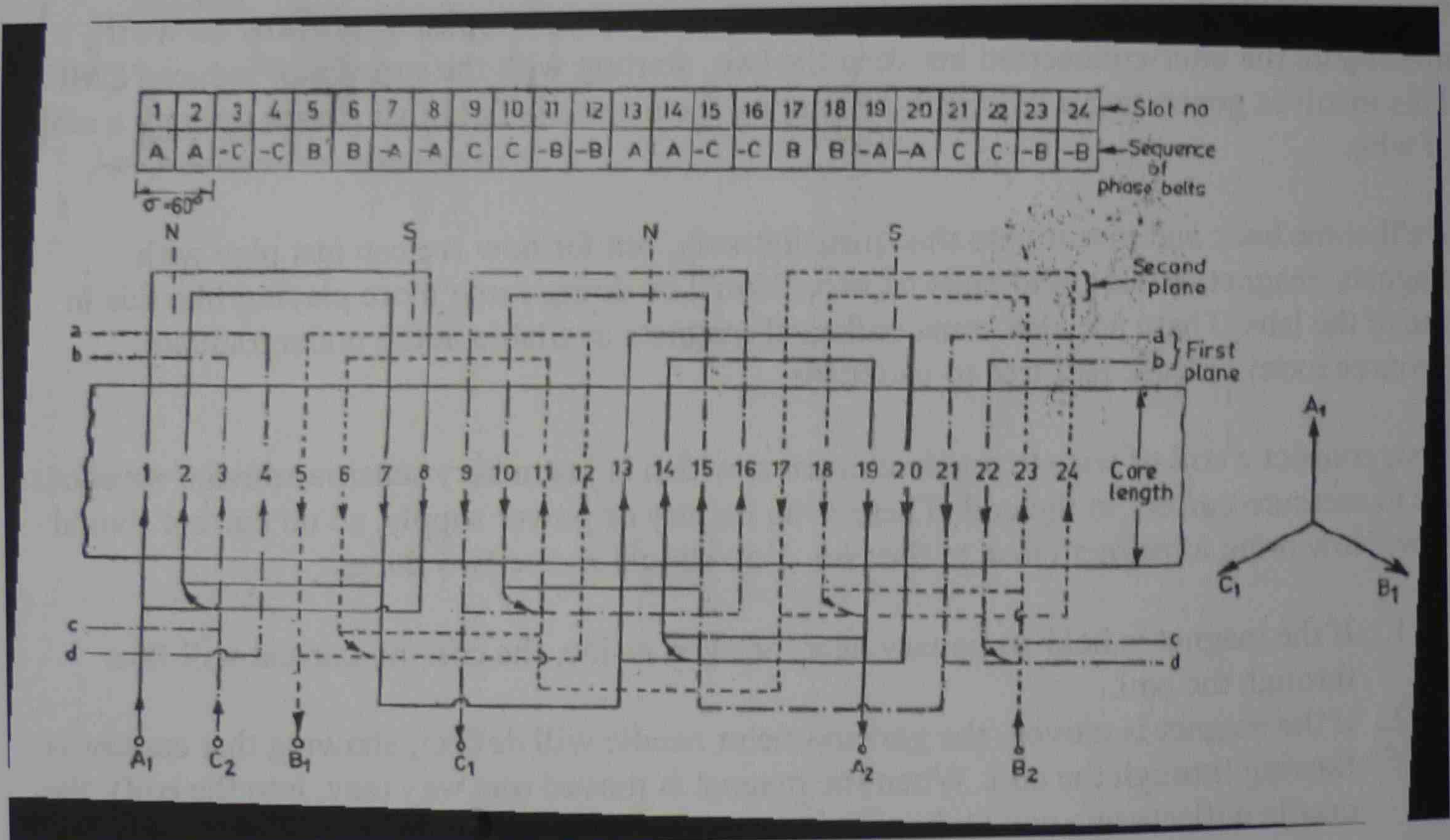


Q5. Design three phase 48 slots 4 poles winding.

The paper presents a new double layer three phase 4 to 6 pole-changing winding, with 48 slots and 6 terminals. In order to obtain a higher fundamental winding factor when winding is 6-pole connected, a degree of asymmetry is accepted for the winding when 4-pole connected.

The new winding is compared with a well known two-layer winding presented in literature. An experimental motor equipped with the new winding was built on a 4-pole base and

frame 100 (2.2/1.5 kW) and tested. At the same time, 2D FEM field-circuit models were developed to simulate the operation of the experimental model equipped with the newly proposed winding, and model equipped with the well known two-layer winding.



Q6. What is distribution factor?

When a joint is released and begins to rotate under the unbalanced moment, resisting forces develop at each member framed together at the joint. Although the total resistance is equal to the unbalanced moment, the magnitudes of resisting forces developed at each member differ by the members' flexural stiffness. Distribution factors can be defined as the proportions of the unbalanced moments carried by each of the members. In mathematical terms, distribution factor of member k framed at joint j is given as:

$$D_{jk} = \frac{L_k}{\sum_{i=1}^n \frac{E_i I_i}{L_i}}$$

where n is the number of members framed at the joint.

Q7. What is coil span factor?

The distance between the two sides of an individual coil of an AC armature winding is termed the coil pitch. When the angular distance between the sides of a coil is exactly equal to the angular distance between the centers of adjacent field poles, the coil is termed to be a full pitch coil. An armature winding made up of full pitch coils is termed a Full Pitch winding.

Q8. How do distribution factor & coil span factor affect the induced emf?

So far we've dealt with electricity and magnetism as separate topics. From now on we'll investigate the inter-connection between the two, starting with the concept of induced EMF. This involves generating a voltage by changing the magnetic field that passes through a coil of wire.

We'll come back and investigate this quantitatively, but for now we can just play with magnets, magnetic fields, and coils of wire. You'll be doing some more playing like this in one of the labs. There are also some coils and magnets available in the undergraduate resource room - please feel free to use them.

First, connect a coil of wire to a galvanometer, which is just a very sensitive device we can use to measure current in the coil. There is no battery or power supply, so no current should flow. Now bring a magnet close to the coil. You should notice two things:

1. If the magnet is held stationary near, or even inside, the coil, no current will flow through the coil.
2. If the magnet is moved, the galvanometer needle will deflect, showing that current is flowing through the coil. When the magnet is moved one way (say, into the coil), the needle deflects one way; when the magnet is moved the other way (say, out of the coil), the needle deflects the other way. Not only can a moving magnet cause a current to flow in the coil, the direction of the current depends on how the magnet is moved.

How can this be explained? It seems like a constant magnetic field does nothing to the coil, while a changing field causes a current to flow.

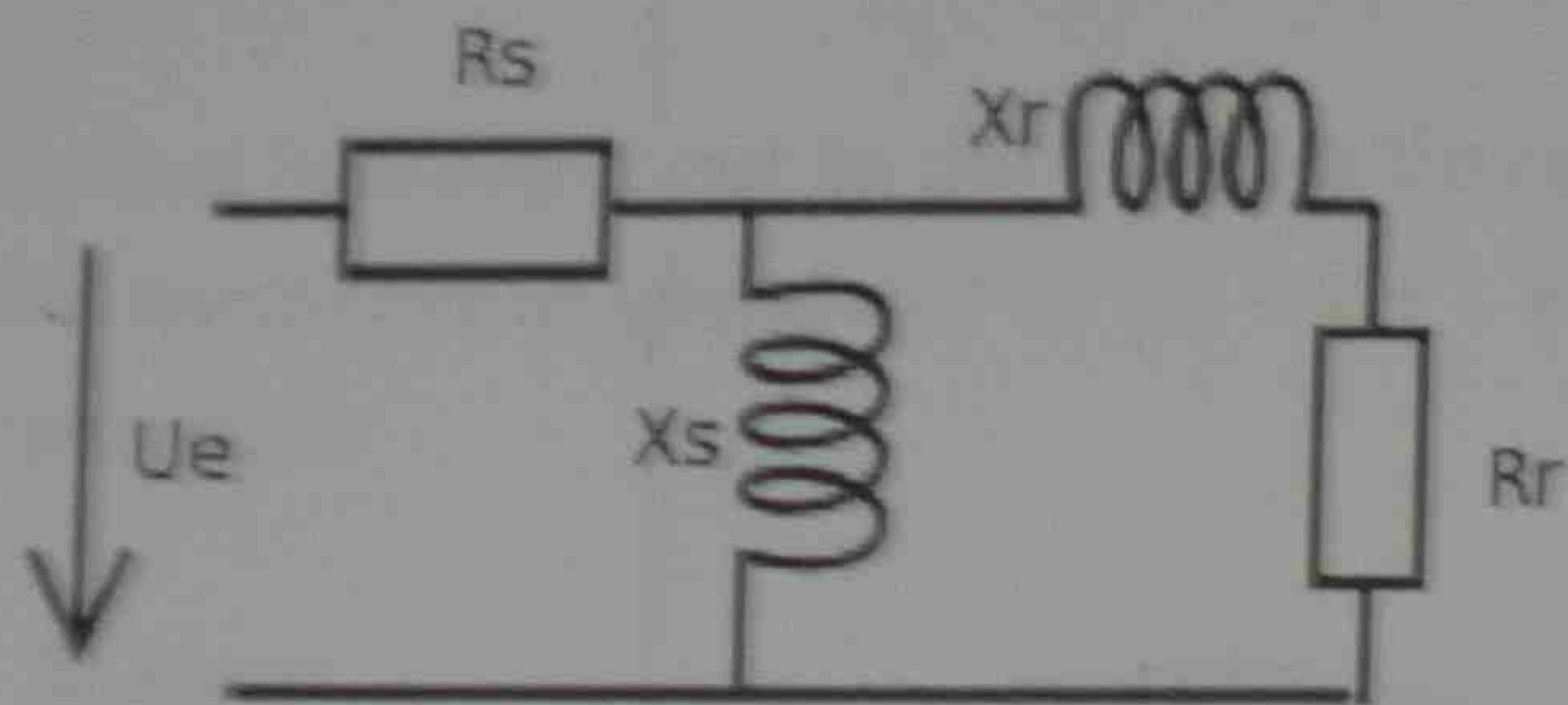
To confirm this, the magnet can be replaced with a second coil, and a current can be set up in this coil by connecting it to a battery. The second coil acts just like a bar magnet. When this coil is placed next to the first one, which is still connected to the galvanometer, nothing happens when a steady current passes through the second coil. When the current in the

responds, indicating that a current is flowing in the first coil.

You also notice one more thing. If you squeeze the first coil, changing its area, while it's sitting near a stationary magnet, the galvanometer needle moves, indicating that current is flowing through the coil.

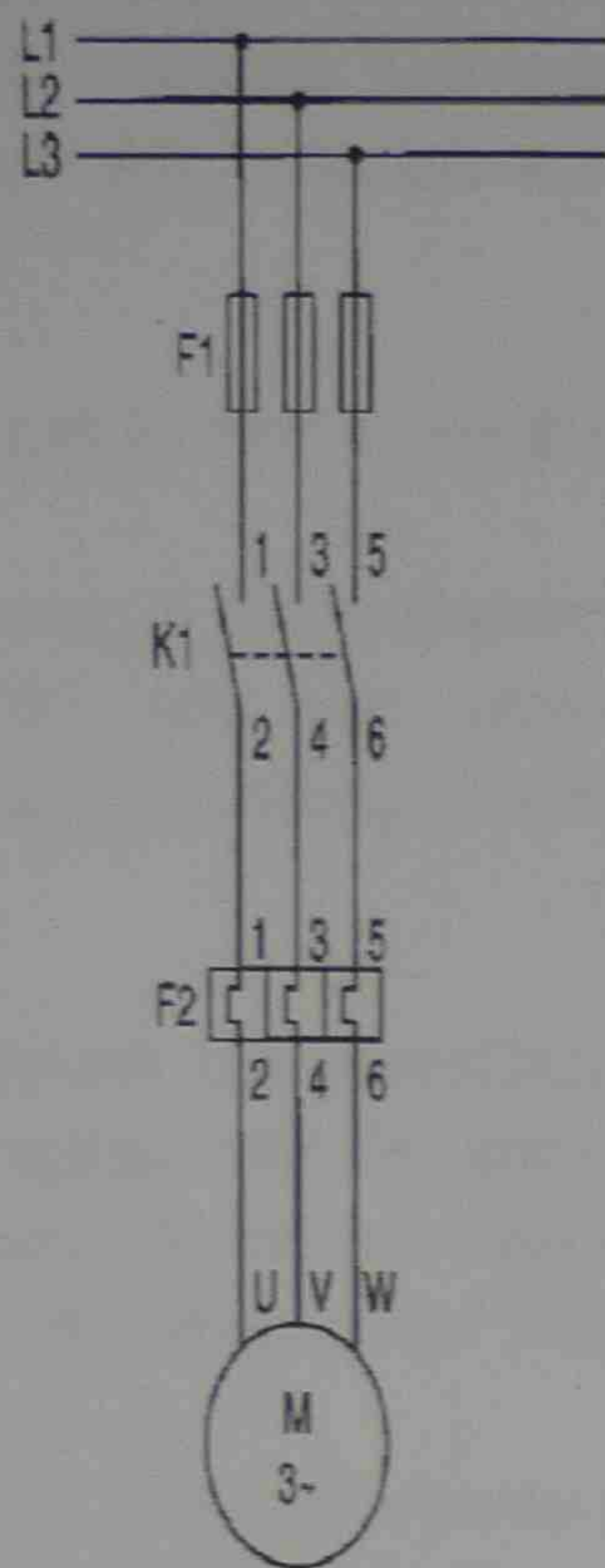
What you can conclude from all these observations is that a changing magnetic field will produce a voltage in a coil, causing a current to flow. To be completely accurate, if the magnetic flux through a coil is changed, a voltage will be produced. This voltage is known as the induced emf.

Q12. Sketch the equivalent circuit & equation of induction motor.

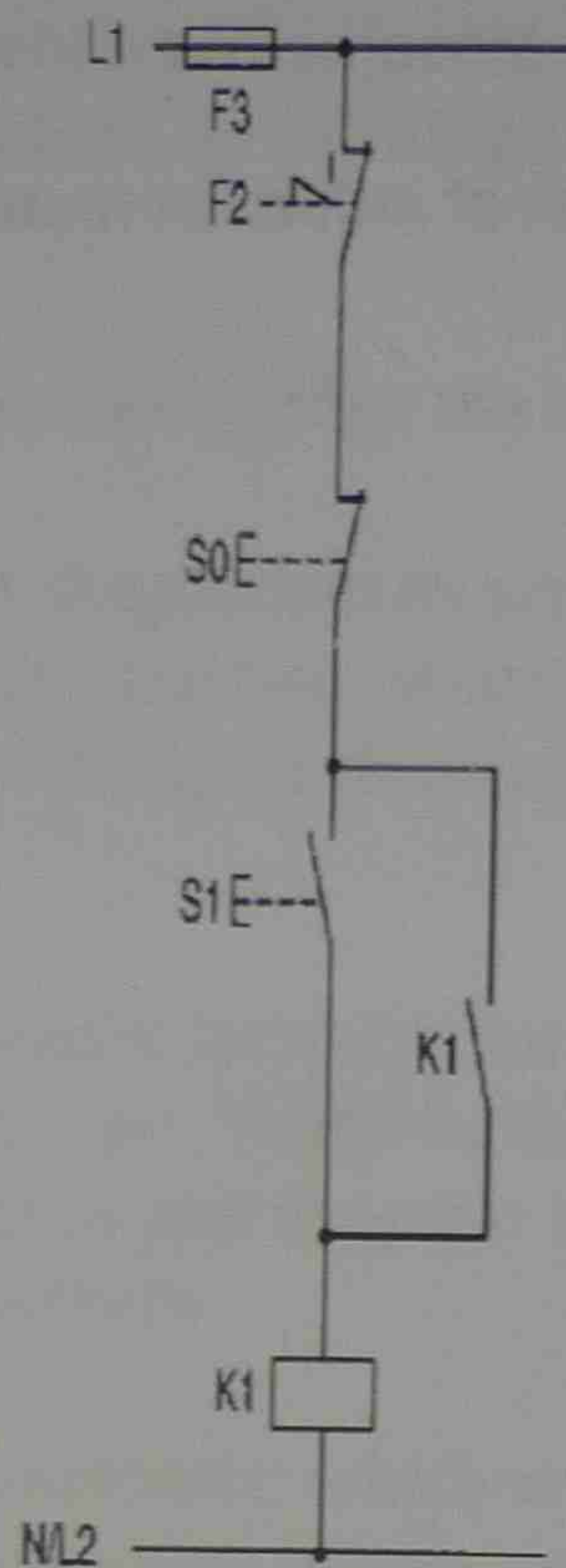


Q13. Sketch DOL starter

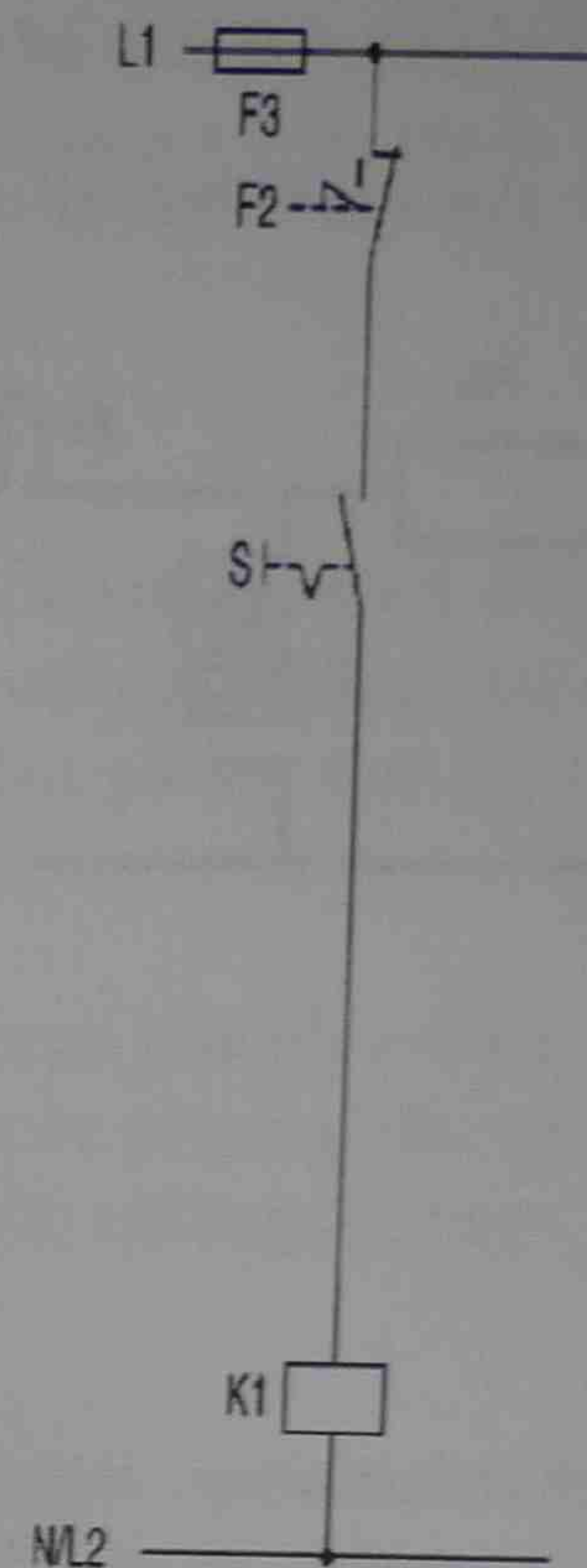
Typical circuit diagram of Direct On Line starter



a) Main circuit



b) Control circuit for momentary-contact control



c) Control circuit for maintained-contact control

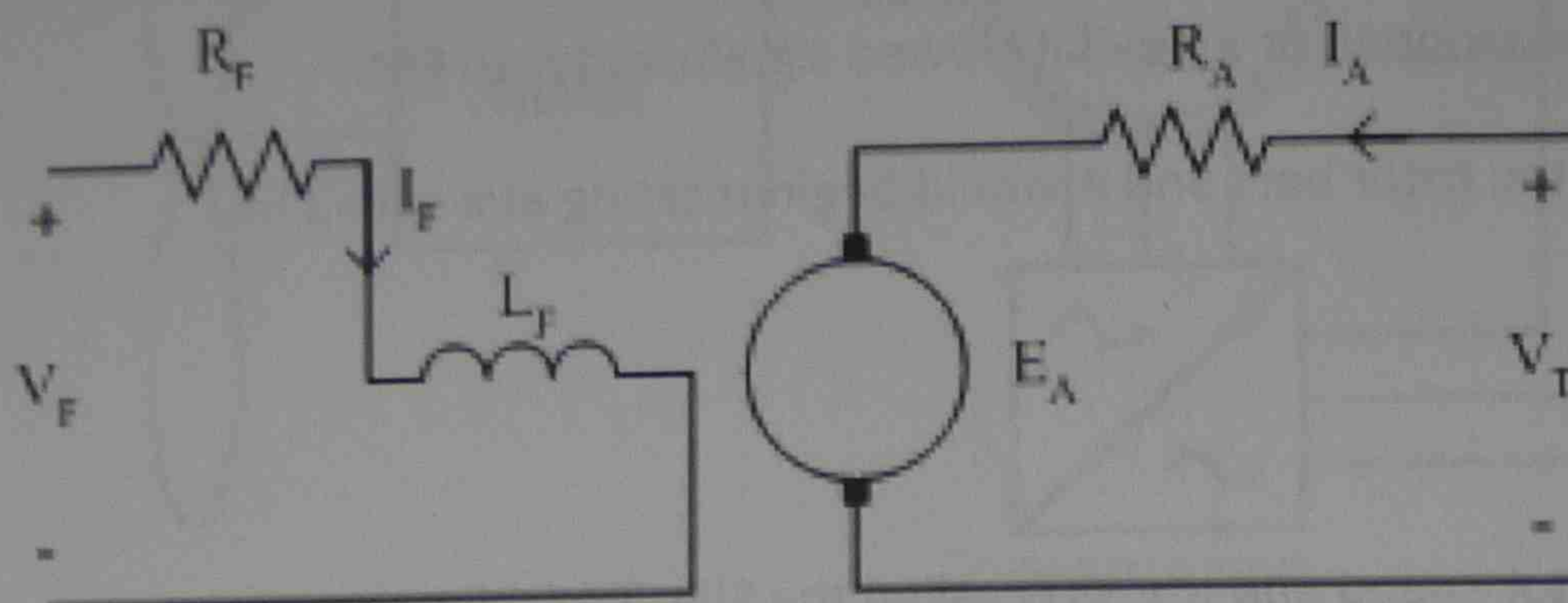
- S0 = 'OFF' Push button
- S1 = 'ON' Push button
- S = Maintained contact
- K1 = Main contactor
- F1 = Main circuit fuse
- F2 = Overload relay
- F3 = Control circuit fuse

Q14. Write equations for locked rotor current & locked rotor torque.

Mechanical Formulas

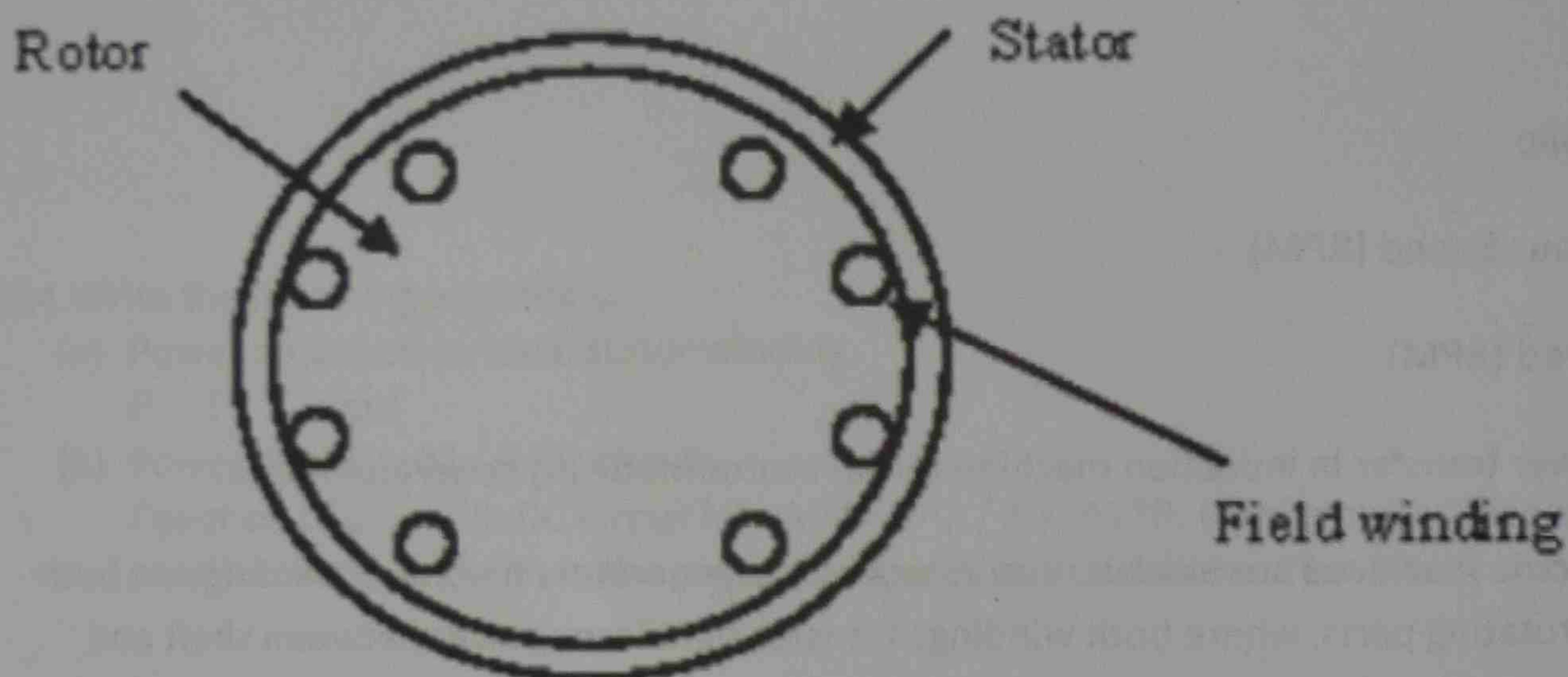
$$\text{Torque in lb.ft.} = \frac{\text{HP} \times 5250}{\text{rpm}} \quad \text{HP} = \frac{\text{Torque} \times \text{rpm}}{5250} \quad \text{rpm} = \frac{120 \times \text{Frequency}}{\text{No. of Poles}}$$

Q20. Write the equation for motor current at stand still condition & any slip.



$$V_f = I_f \cdot R_f$$

current is brought out to the load via three (or four) slip-rings. Insulation ... The circuit equation of the synchronous generator is: $f s. = V + I \cdot E \cdot Z$... generator may operate in one of the operating conditions



The armature winding is on the stator and the field system is on the rotor. Field current is supplied from the exciter via two slip-rings, while the armature current is directly supplied to the load. This type is employed universally since very high power can be delivered.

Unless otherwise stated, the subsequent discussion refers specifically to rotating-field type synchronous machines.

MOTOR SLIP

The rotor in an induction motor can not turn at the synchronous speed. In order to

induce an EMF in the rotor, the rotor must move slower than the SS. If the rotor were to somehow turn at SS, the EMF could not be induced in the rotor and therefore the rotor would stop. However, if the rotor stopped or even if it slowed significantly, an EMF would once again be induced in the rotor bars and it would begin rotating at a speed less than the SS.

The relationship between the rotor speed and the SS is called the Slip. Typically, the Slip is expressed as a percentage of the SS. The equation for the motor Slip is:

$$\% S = \{(SS - RS)/SS\} \times 100$$

Where:

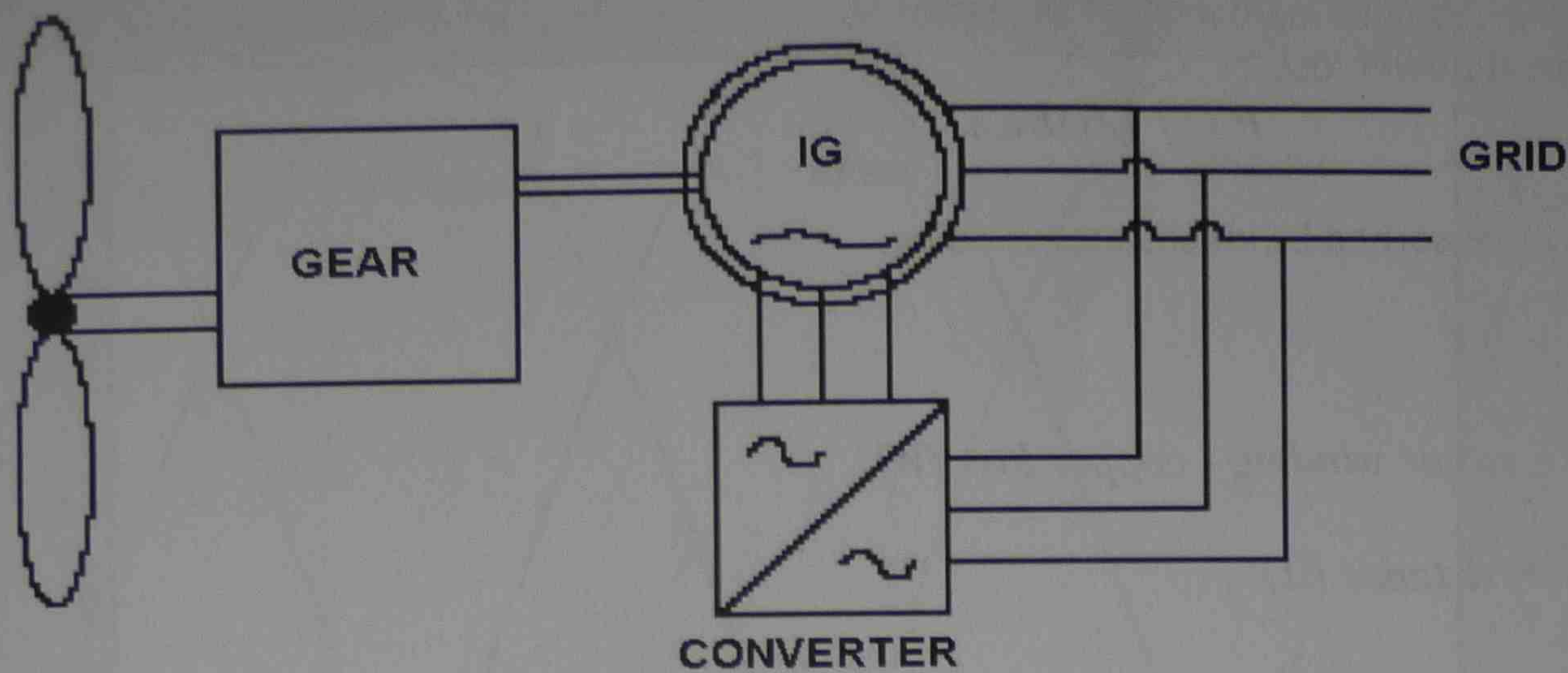
%S = Percent Slip

SS = Synchronous Speed (RPM)

RS = Rotor Speed (RPM)

Q23. Sketch power transfer in induction machine for (a) motor mode (b) generator mode.

Doubly-fed electric machines are electric motors or electric generators that have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and electrical system. Doubly-fed machines are useful in applications that require varying speed of the machine's shaft for a fixed power system frequency.



PRINCIPLE OF DFIG CONNECTED TO A WIND TURBINE

Q24. Write the following equations.

(a) Power absorbed by ideal stator winding

$$P = I \cdot V \text{ ccmf}$$

(b) Power dissipated in rotor circuit.

Equation of power in DC Circuit? $P = V \cdot I = V^2 / R = I^2 \cdot R$. Is the power dissipated in a parallel circuit larger than the power dissipated in a serial circuit?

$$P = IV$$

P = power

I = current

V = voltage

(c) Mechanical power $W = F \cdot \Delta d$

(d) Power dissipated in rotor resistance $P_{\text{rot}} = M \cdot W$

P_{rot} = rotational mechanical power

M = torque

w = angular velocity

(a) Motor circuit power loss

$$P = I^2 R$$

(b) Power absorbed by ideal motor winding

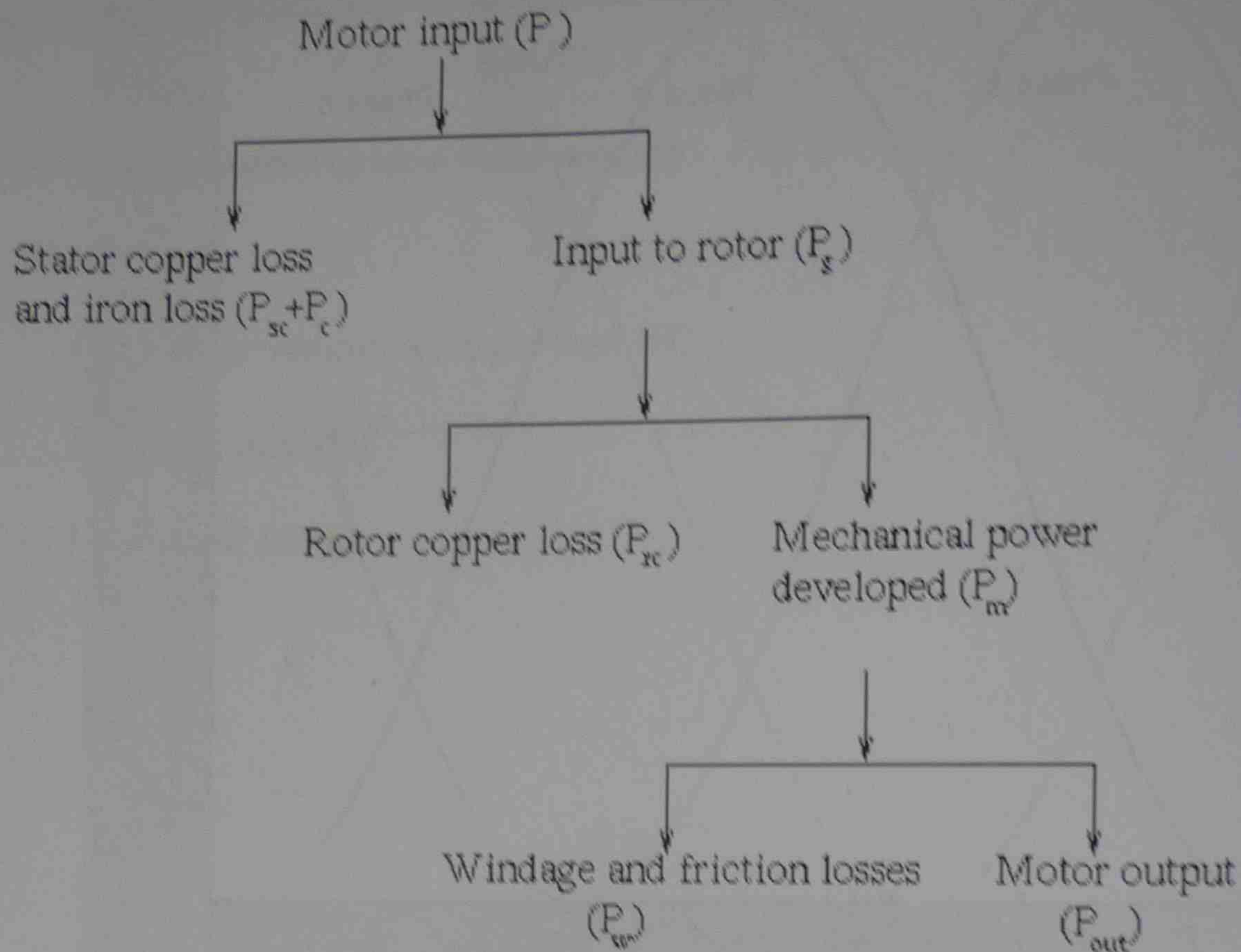
$$(c) P_s = RI^2$$

P_s = motor winding = copper loss (W)

R = resistance (Ω)

I = current (Amp)

Q25 Sketch the power flow diagram in motor



Q27. Write the equation for

(a) Mechanical power developed by rotor

$$P_m = E_b I_a$$

V = applied voltage

E_b = back e.m.f.

R_a = armature resistance

I_a = armature current

(b) Mechanical power delivered to load.

$$\text{Now } P_m = VI_a - I_a^2 R_a$$

Since, V and R_a are fixed, power developed by the motor depends upon armature current. For maximum power, dP_m/dI_a should be zero.

$$dP_m/dI_a = V - 2I_a R_a$$

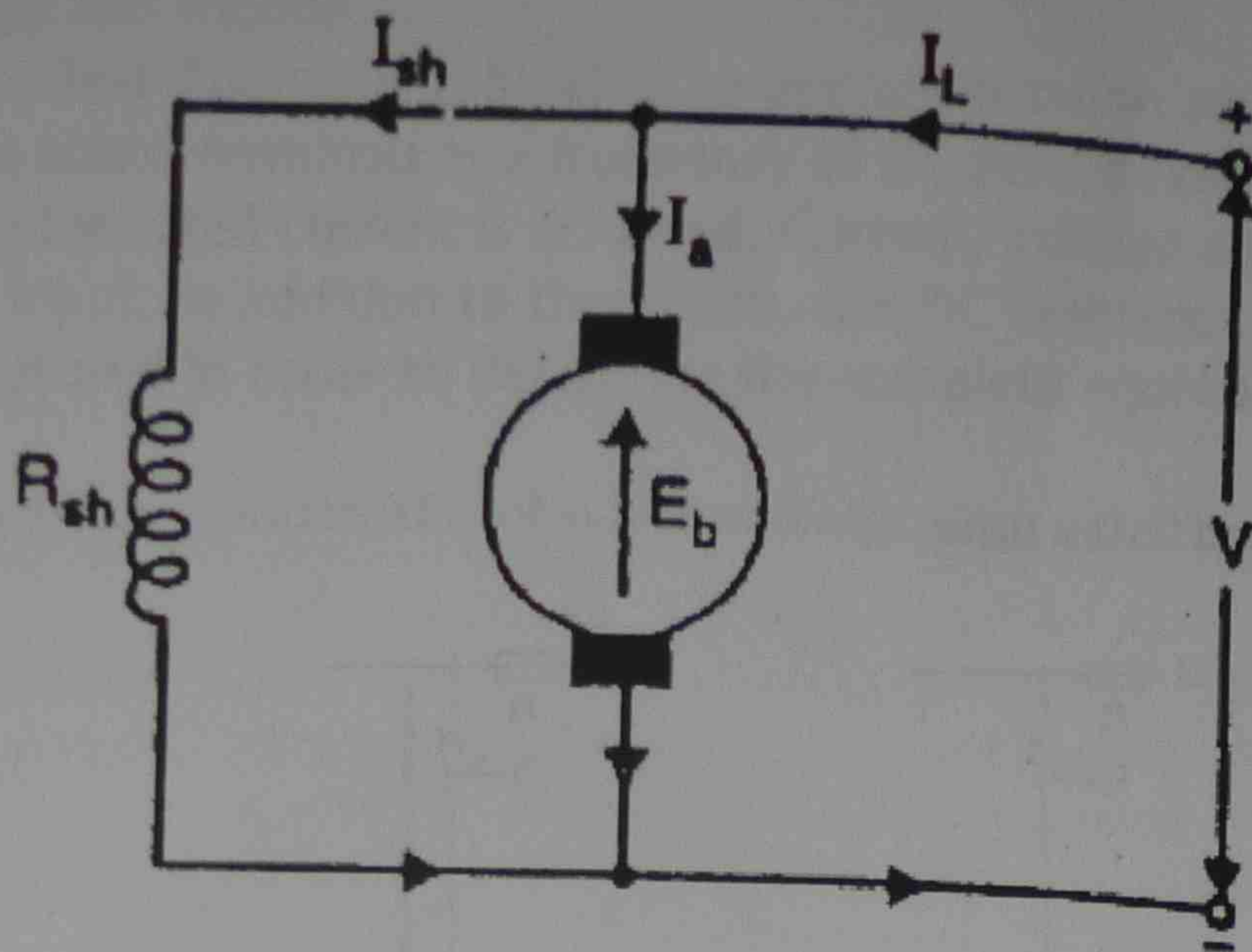


Fig. (4.3)

or $I_a R_a = V/2$

Now, $V = E_b + I_a R_a = E_b + V/2$

therefore $E_b = V/2$

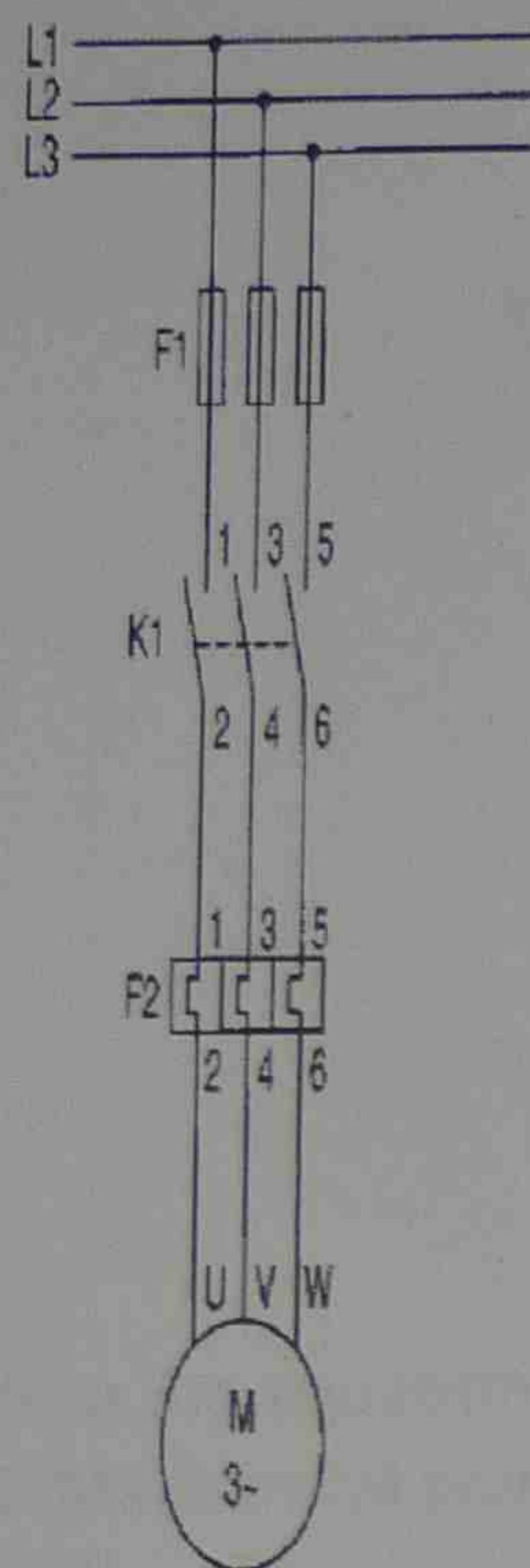
(c) Mechanical torque. $T = r \cdot F$

Q31. Describe the motor reduced voltage starting methods.

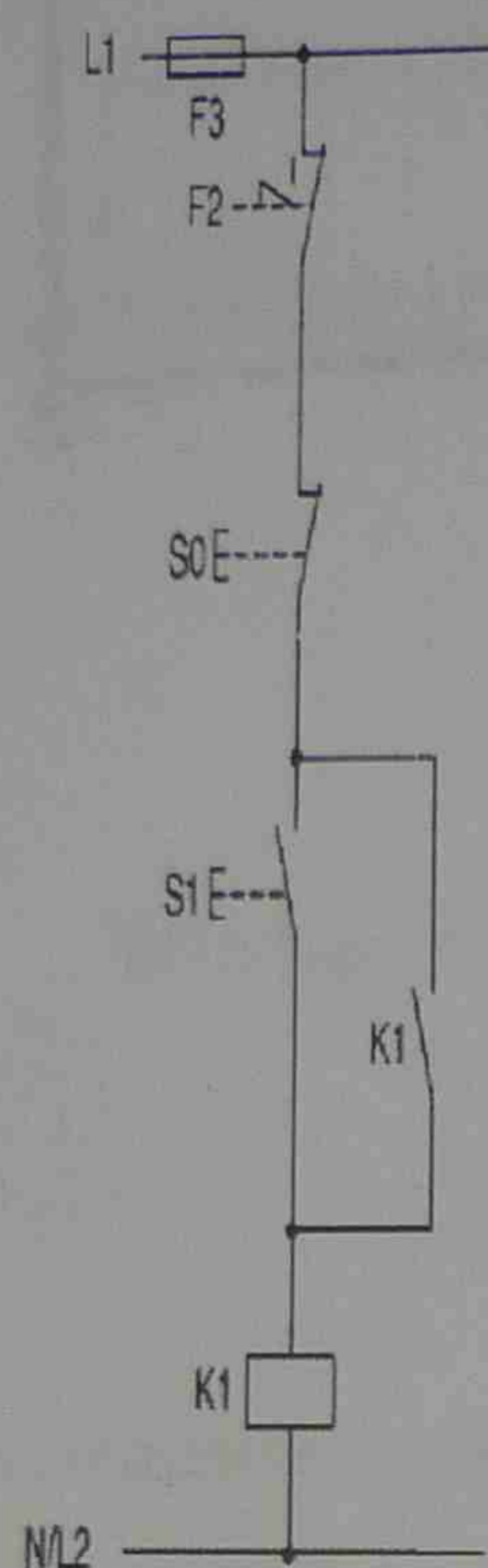
Two or more contactors may be used to provide reduced voltage starting of a motor. By using an autotransformer or a series inductance, a lower voltage is present at the motor terminals, reducing starting torque and inrush current. Once the motor has come up to some fraction of its full-load speed, the starter switches to full voltage at the motor terminals. Since the autotransformer or series reactor only carries the heavy motor starting current for a few seconds, the devices can be much smaller compared to continuously-rated equipment. The transition between reduced and full voltage may be based on elapsed time, or triggered when a current sensor shows the motor current has begun to reduce.

Q32. Sketch DOL starter.

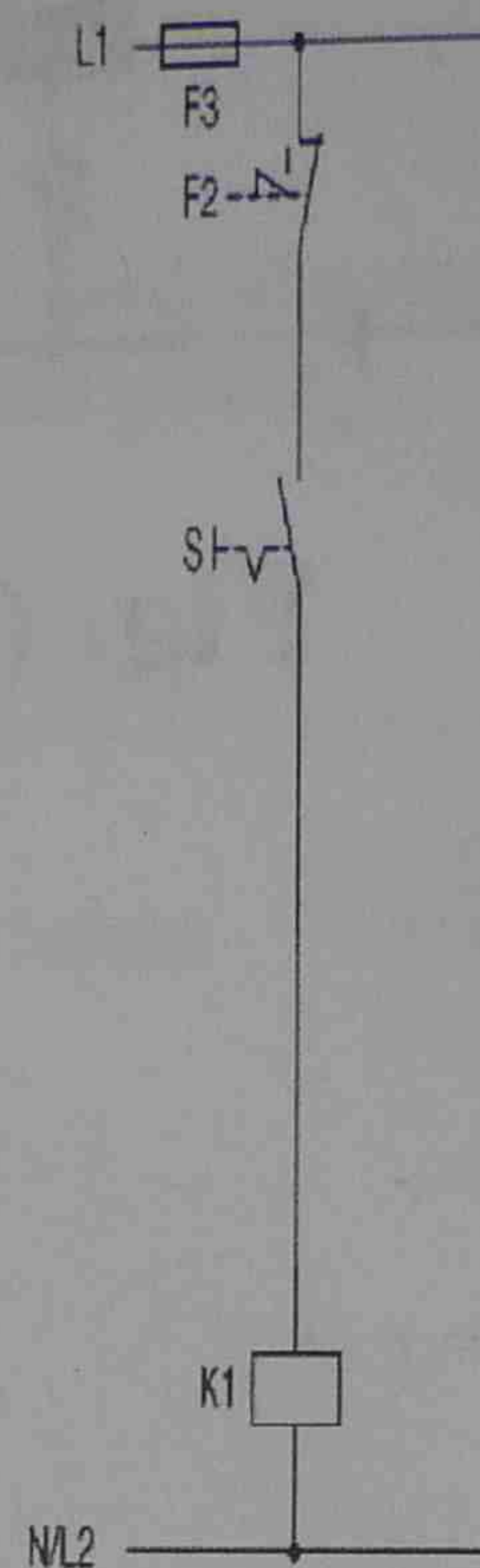
Typical circuit diagram of Direct On Line starter



a) Main circuit



b) Control circuit for momentary-contact control



c) Control circuit for maintained-contact control

- S0 = 'OFF' Push button
- S1 = 'ON' Push button
- S = Maintained command switch
- K1 = Main contactor
- F1 = Main circuit fuse
- F2 = Overload relay
- F3 = Control circuit fuse

Q33. Explain the tests to determine the equivalent circuit of three phase motor.

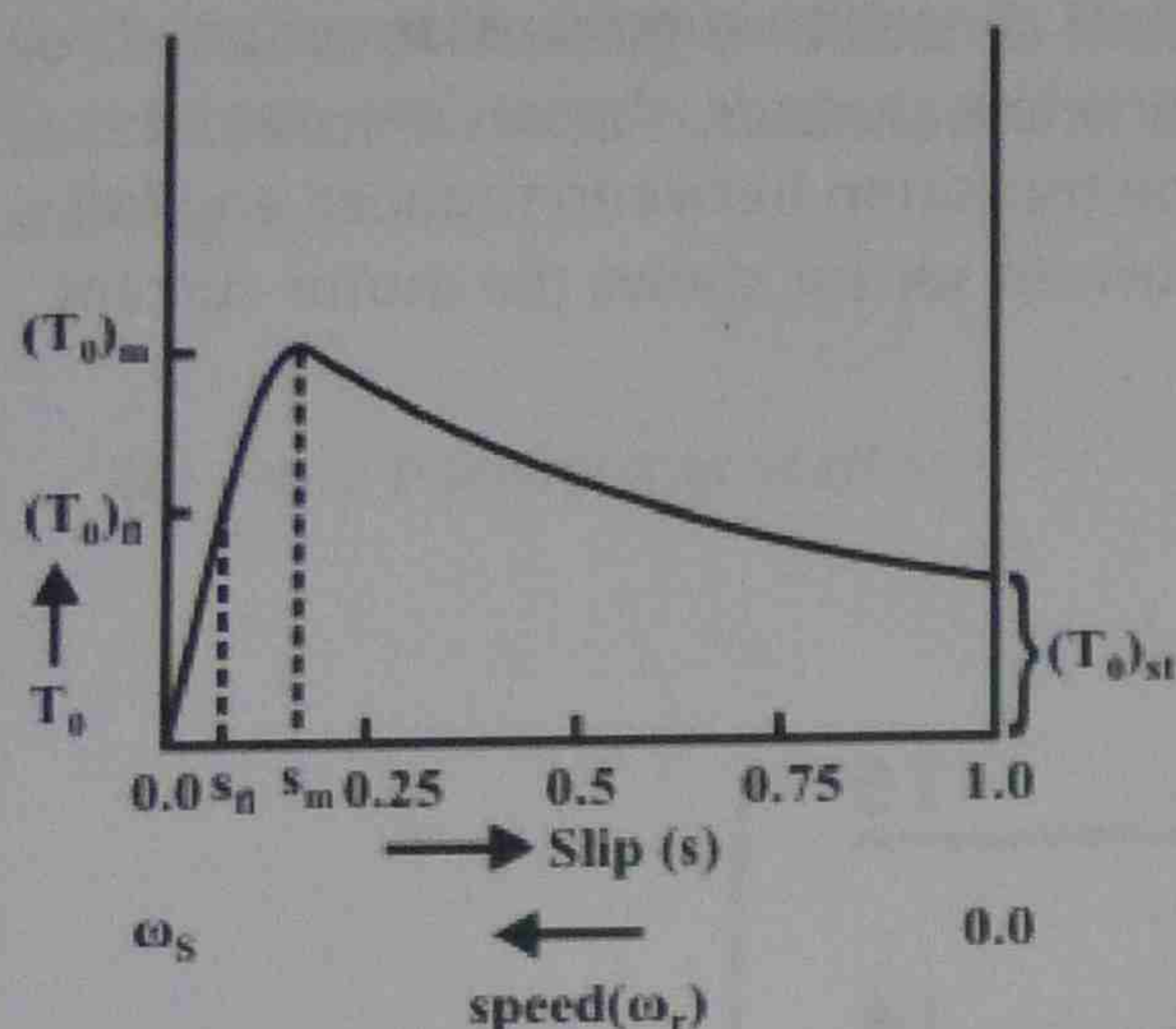
The equivalent circuit parameters for an induction motor can be determined using specific tests on the motor, just as was done for the transformer.

No-Load Test Balanced voltages are applied to the stator terminals at the rated frequency with the rotor uncoupled from any mechanical load. Current, voltage and power are measured at the motor input. The losses in the no-load test are those due to core losses, winding

losses, windage and friction.

Blocked Rotor Test The rotor is blocked to prevent rotation and balanced voltages are applied to the stator terminals at a frequency of 25 percent of the rated frequency at a voltage where the rated current is achieved. Current, voltage and power are measured at the motor input. In addition to these tests, the DC resistance of the stator winding should be measured in order to determine the complete equivalent circuit.

Q44. Sketch slip torque characteristics of induction motor.



: Torque-slip(speed) characteristics of Induction Motor

Q45. Explain stability & crawling.

In control, stability captures the reproducibility of motions and the robustness to environmental and internal perturbations. This paper examines how stability can be evaluated in human movements, and possible mechanisms by which humans ensure stability. First, a measure of stability is introduced, which is simple to apply to human movements and corresponds to Lyapunov exponents. Its application to real data shows that it is able to distinguish effectively between stable and unstable dynamics. A computational model is then used to investigate stability in human arm movements, which takes into account motor output variability and computes the force to perform a task according to an inverse dynamics model. Simulation results suggest that even a large time delay does not affect movement stability as long as the reflex feedback is small relative to muscle elasticity. Simulations are also used to demonstrate that existing learning schemes, using a monotonic antisymmetric update law, cannot compensate for unstable dynamics. An impedance compensation algorithm is introduced to learn unstable dynamics, which produces similar adaptation responses to those found in experiments.

A theory of coexisting stationary and rotating slot openings is developed with the aid of "revolving permeances," and the magnitude and speed of the parasitic fluxes due to the slot openings and the fundamental current density wave are found. It is shown that the interaction of the fundamental flux and a parasitic flux of the same order of magnitude as the fundamental flux causes the vibrations, objectionable noises, and crawlings of induction motors. The existence of these ruinous irregularities depends only in the difference of slots, the number of poles, and in some cases on the critical speeds of the rotor for circular or torsional vibrations, and is independent of the number of phases or the

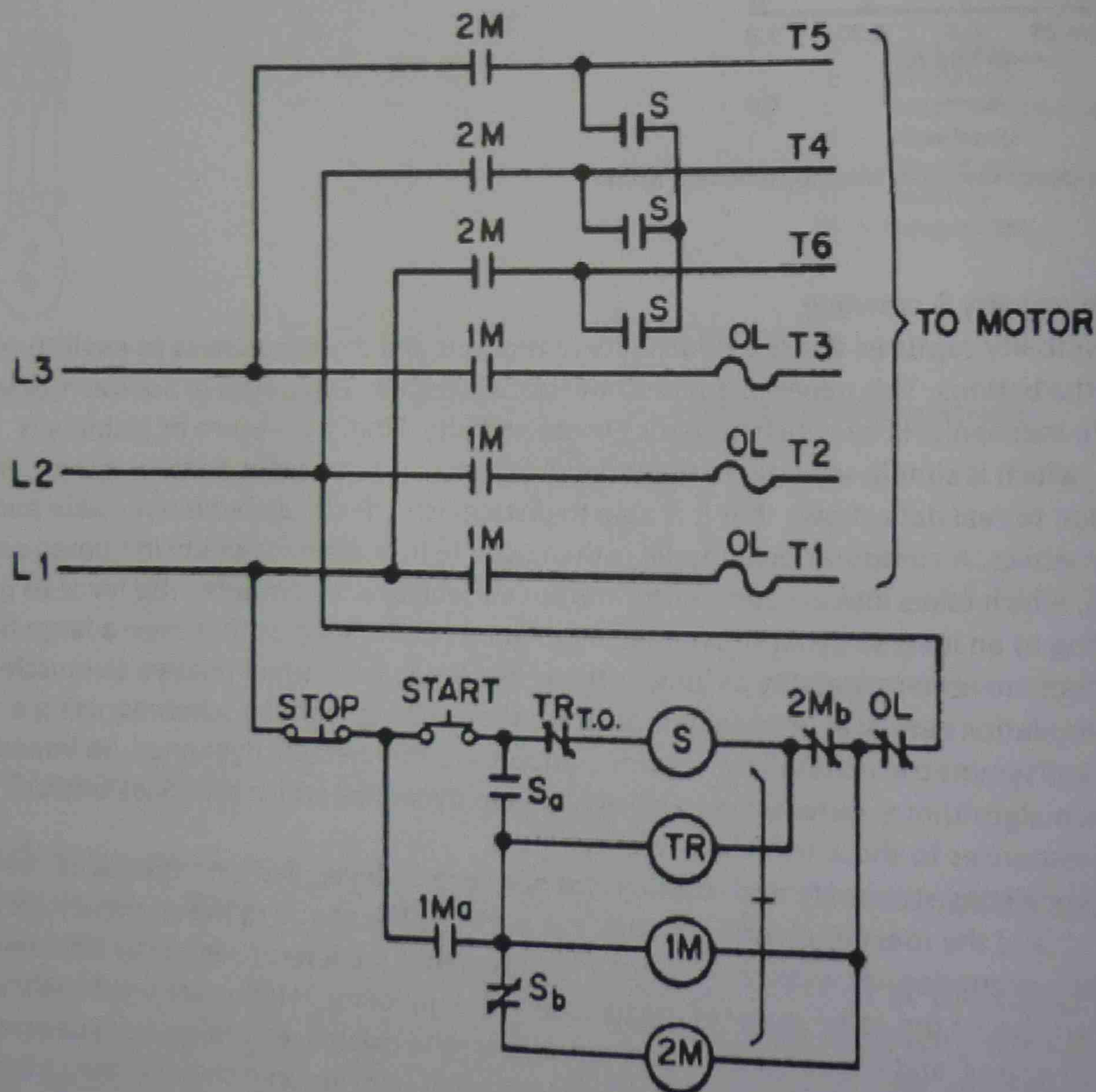
type of winding. Three rules are developed for the determination of destructive vibrations and noise, eight rules for establishing crawling speeds, and eight rules for finding hooks in the speed-torque curves of induction motors.

Q46. Why does reduced starting voltage needed to start the induction motor and write the types of reduced voltage starters.

Two or more contactors may be used to provide reduced voltage starting of a motor. By using an autotransformer or a series inductance, a lower voltage is present at the motor terminals, reducing starting torque and inrush current. Once the motor has come up to some fraction of its full-load speed, the starter switches to full voltage at the motor terminals. Since the autotransformer or series reactor only carries the heavy motor starting current for a few seconds, the devices can be much smaller compared to continuously-rated equipment. The transition between reduced and full voltage may be based on elapsed time, or triggered when a current sensor shows the motor current has begun to reduce.

Q47. Explain the followings with sketches.

(a) Star delta starter

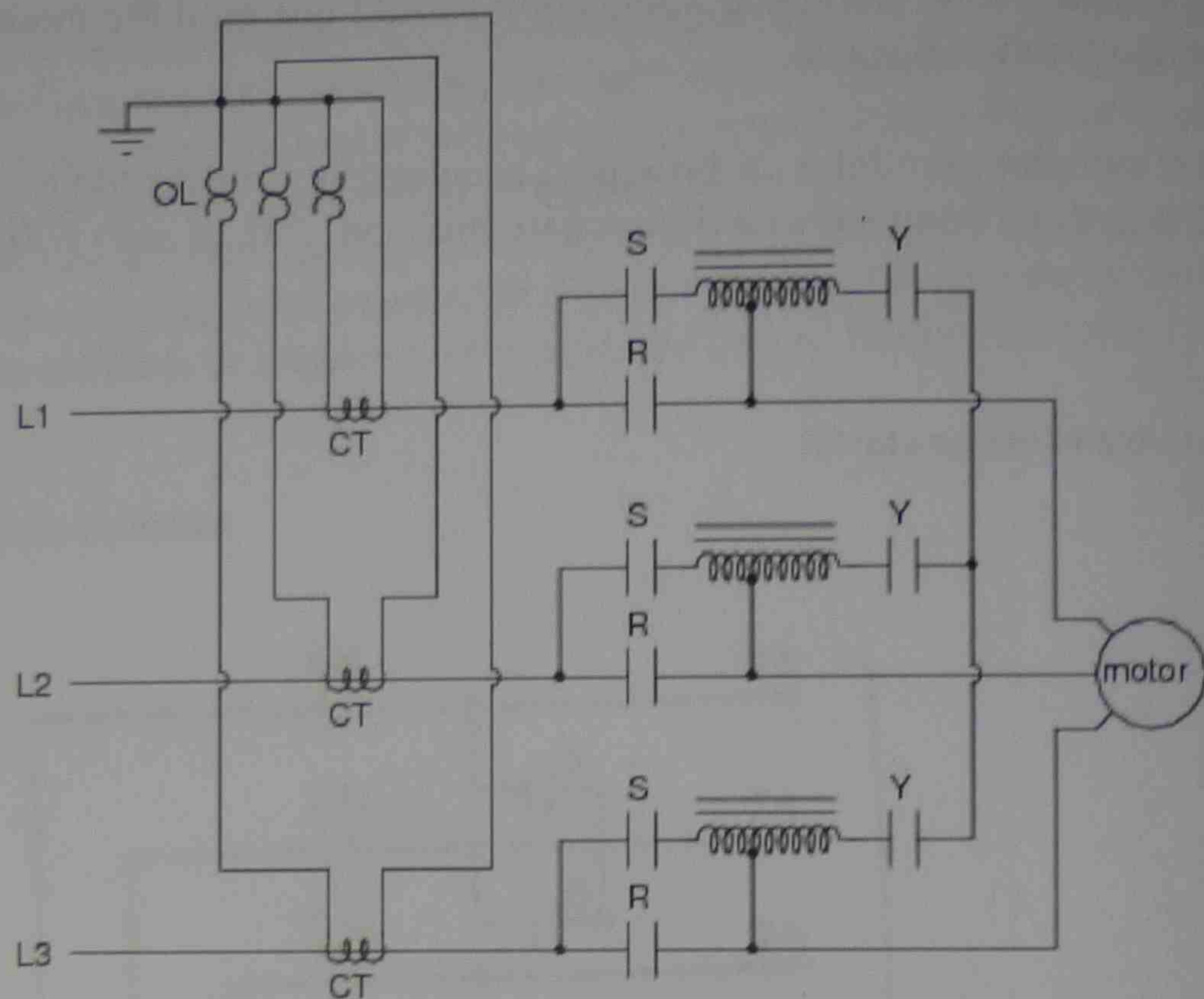


Due to the reduced starting torque, the star-delta-connection is suitable for drives with a high inertia mass but a resistance torque which is low or only increases with increased speed. It is preferably used for applications where the drive is only put under a load after run-up.

After motor run-up, in most cases an automatic timing relay controls the switch-over from star to delta. The run-up using star connection should last until the motor has reached the approximate operational speed.

so that after switching to delta, as little post acceleration as possible is required. Post-acceleration in delta connection will instigate high currents as seen with direct on-line starting.

(b) Auto transformer starter



Motor stationary . If all switches are open the motor is completely disconnected from the three-phase network.

Soft start (phase 1): In order to start the motor first the switches **1** and **2** are closed. This the motor is supplied from a voltage lowered by the autotransformer. The lower voltage limits the input current to the initially stationary motor, which starts to gain rotational speed. The torque of the motor is also lowered accordingly.

Soft start (phase 2)

The motor continues to increase its speed until the motor torque and the load torque balance each other and a steady speed is achieved. At this stage switch 2 is opened and momentarily the motor is supplied by even lower voltage, because the windings of the autotransformer act as inductors connected in series with motor. This time is short - just enough to disconnect the switch 2 and engage switch 3, which connects the full voltage to the motor. Further increase in speed begins and motor reaches its full rated speed.

At this point the "soft start" is ended and motor can work under full load.

Full load

When motor is started up, there is no more need for the autotransformer to be energised. At this stage switch 1 can be safely open to break the supply to the autotransformer, whilst the motor is supplied directly from the three-phase network.

Switch off

In order to de-energise the full started motor it is enough to open the only closed switch 3. The motor returns to the stationary position.

Slip ring motor.

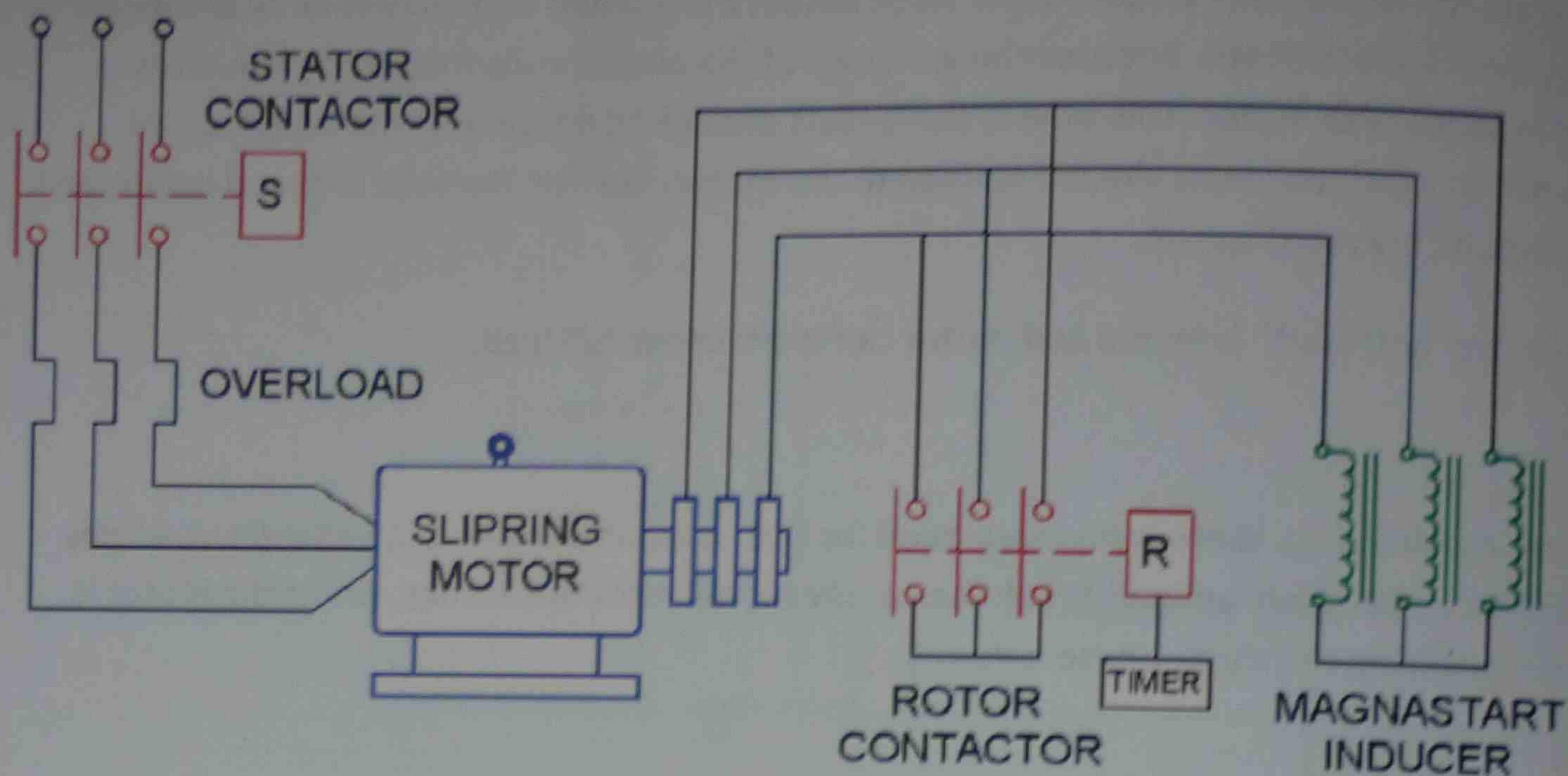
A **slip ring motor** or **wound-rotor motor** is a type of induction motor. The rotor windings are connected to a slip ring, connected to external resistances, which allows controlling the speed/torque characteristic of the motor. Wound-rotor motors can be started with low inrush current, by inserting high resistance into the rotor circuit; as the motor accelerates, the resistance can be decreased.

The rotor of the slip ring motor has more windings than a squirrel-cage rotor so that induction voltage is higher and the current for the same field strength lower. During the start-up a typical rotor has 3 poles connected to the slip ring. Each pole is wired in series with a variable power resistor. When the motor reaches full speed the rotor poles are switched to short circuit becoming a standard squirrel-cage motor. During start-up the resistors reduce the field strength in the stator. As a result the inrush current is reduced. Another important advantage over squirrel-cage motors is higher start-up torque.

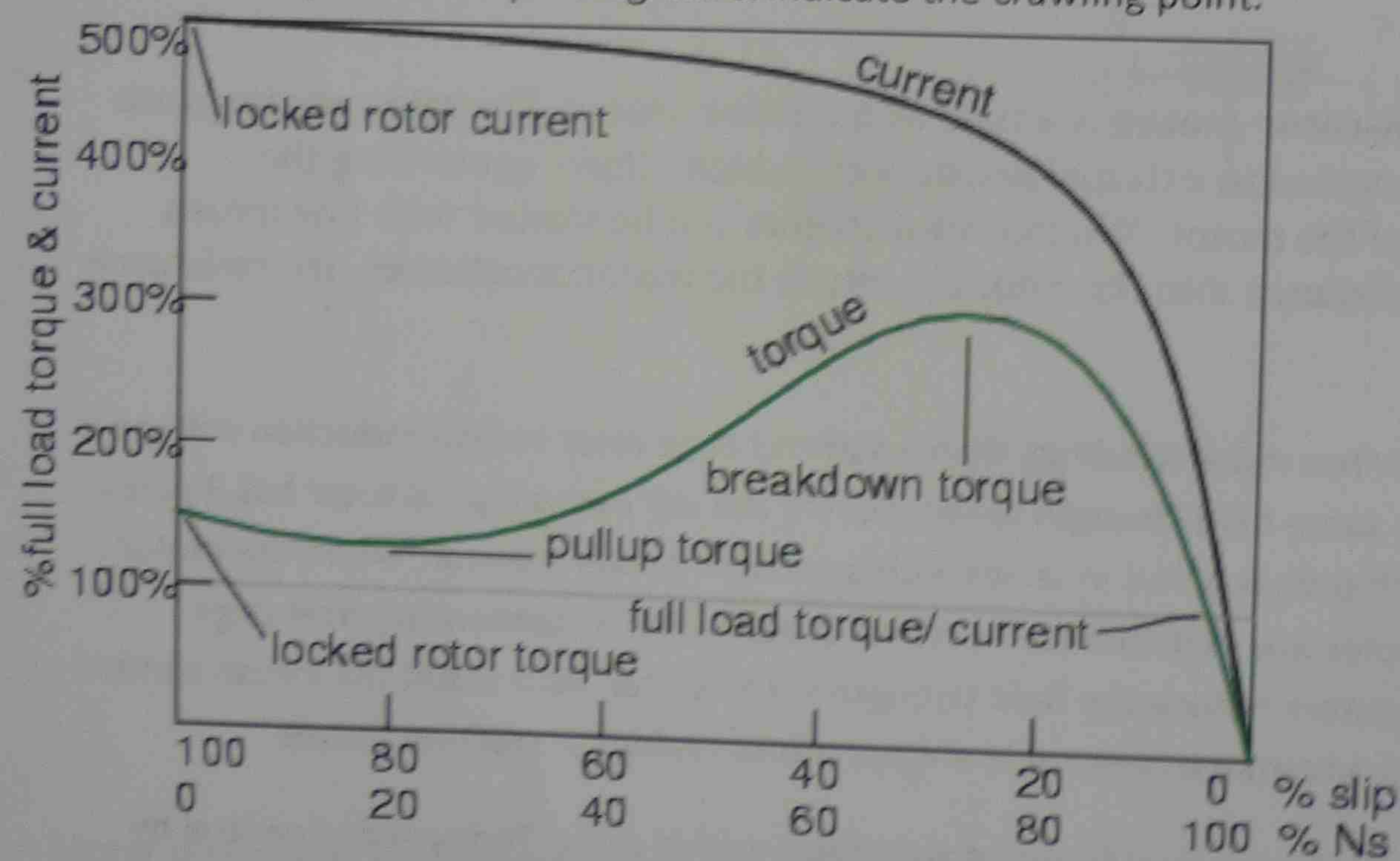
A wound-rotor motor can be used in several forms of adjustable-speed drive. Today speed control by use of slip ring motor is mostly superseded by induction motors with variable-frequency drives.

Doubly-fed electric machines use the slip rings to supply external power to the rotor circuit, allowing wide-range speed control.

Certain types of variable-speed drives recover slip-frequency power from the rotor circuit and feed it back to the supply, allowing wide speed range with high energy efficiency.

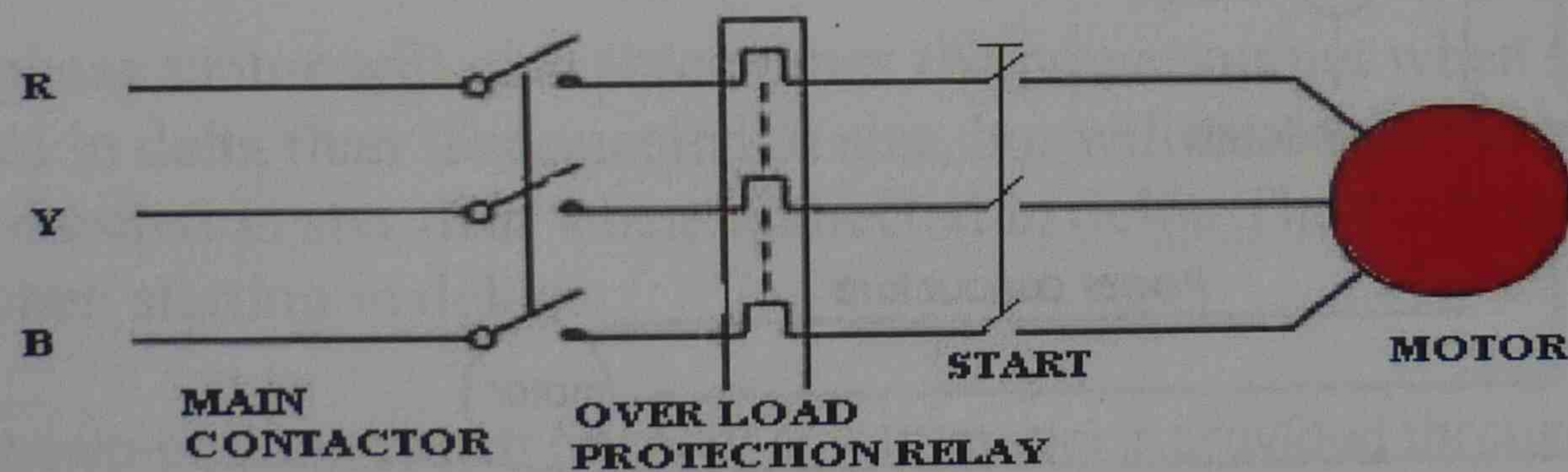
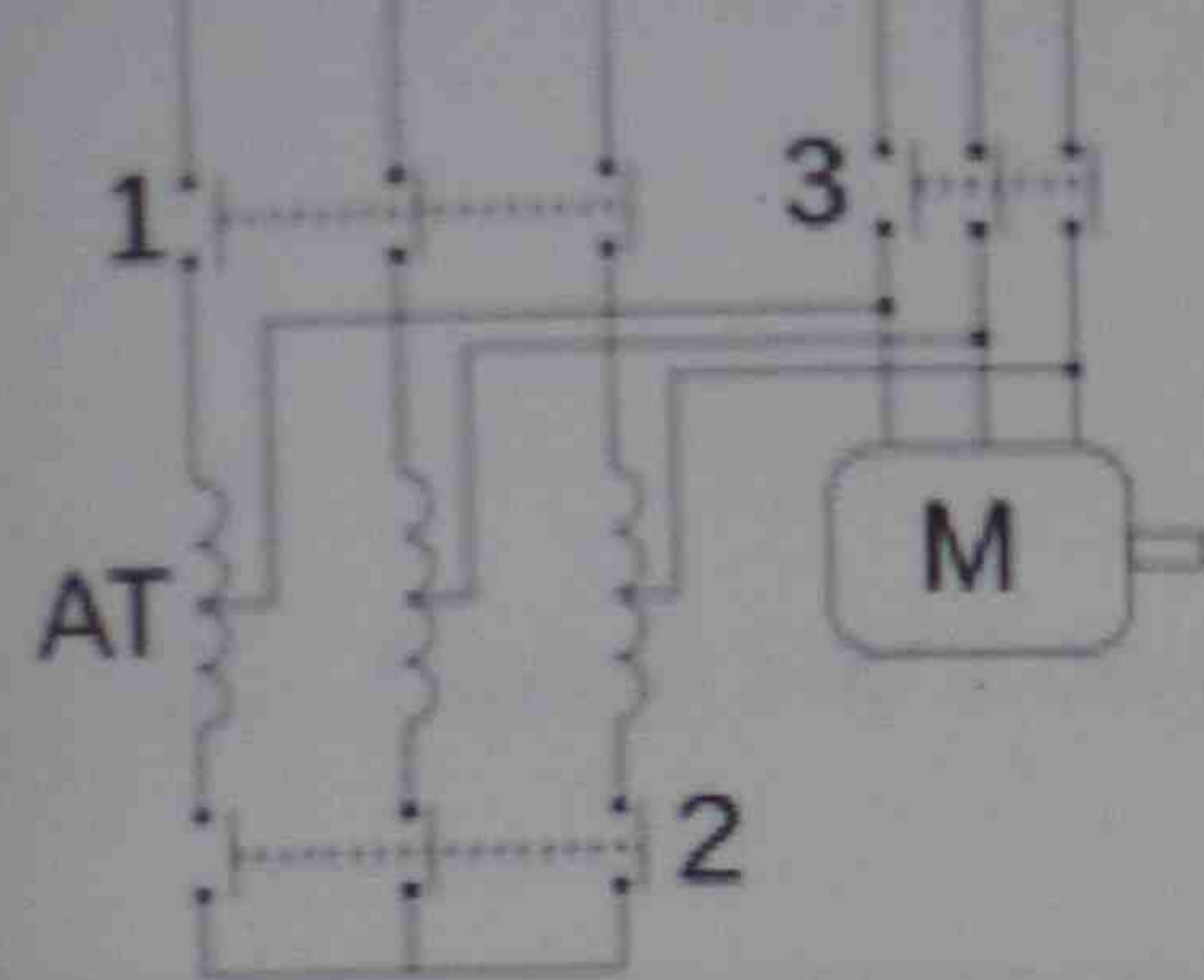


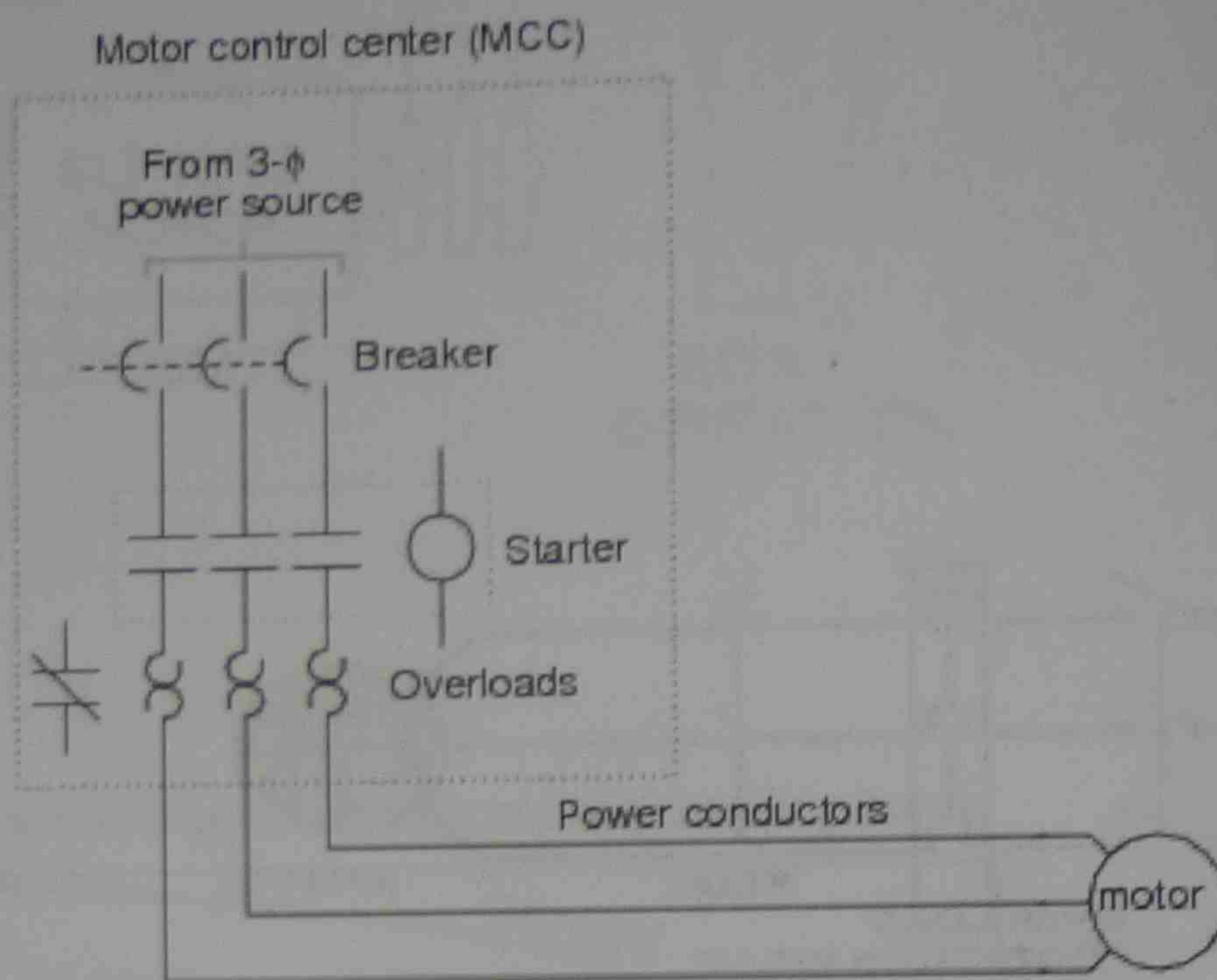
Q48. Sketch the speed & torque diagram & indicate the crawling point.



Torque and speed vs %Slip. $\%N_s = \% \text{Synchronous Speed}$.

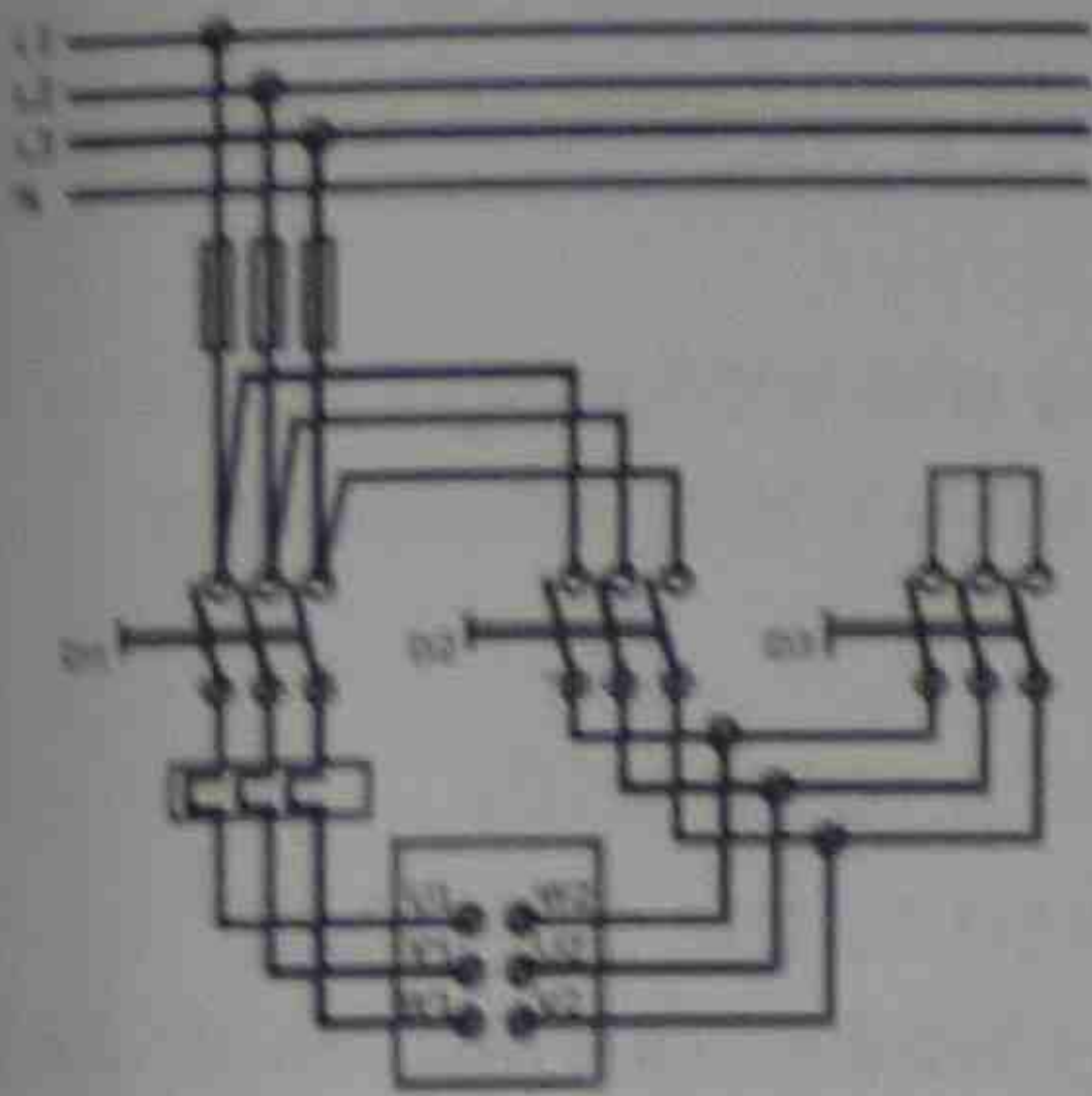
Q50. Explain automatic voltage starter with sketch.





1. Operated by a two position switch i.e. manually / automatically using a timer to change over from start to run position.
2. In starting position supply is connected to stator windings through an auto-transformer which reduces applied voltage to 50, 60, and 70% of normal value depending on tapping used.
3. Reduced voltage reduces current in motor windings with 50% tapping used motor current is halved and supply current will be half of the motor current. Thus starting current taken from supply will only be 25% of the taken by DOL starter.
4. For an induction motor, torque T is developed by V^2 , thus on 50% tapping, torque at starting is only $(0.5V)^2$ of the obtained by DOL starting. Hence 25% torque is produced.
5. Starters used in larger industries, it is larger in size and expensive.

Q51. Explain Star / delta starter with sketch.



A three phase motor will give three times the power output when the stator windings are connected in delta than if connected in star, but will take $\frac{1}{3}$ of the current from the supply when connected in star than when connected in delta. The starting torque developed in star is $\frac{1}{2}$ that when starting in delta.

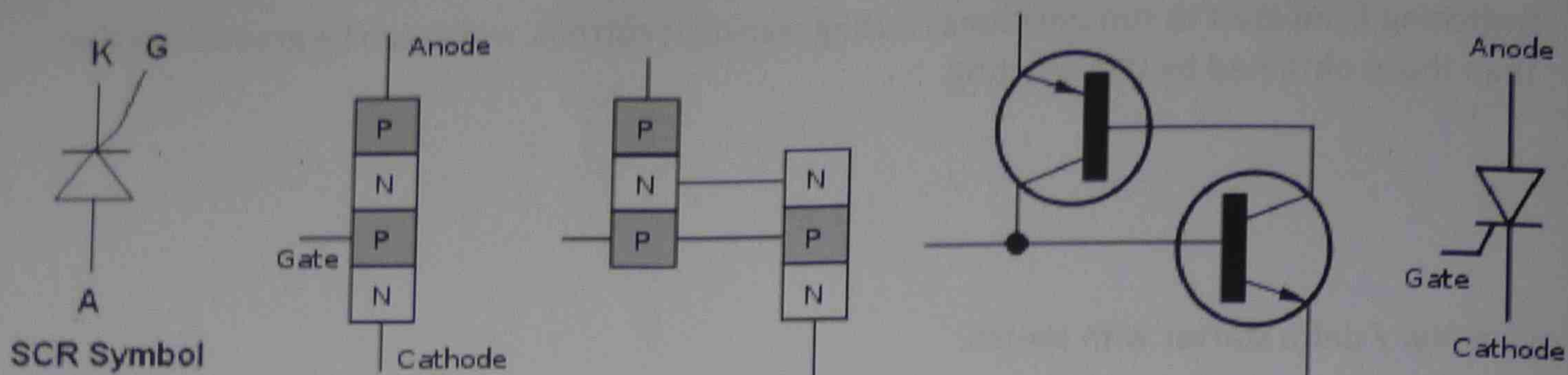
1. A two-position switch (manual or automatic) is provided through a timing relay.
2. Starting in star reduces the starting current.
3. When the motor has accelerated up to speed and the current is reduced to its normal value, the starter is moved to run position with the windings now connected in delta.
4. More complicated than the DOL starter, a motor with a star-delta starter may not produce sufficient torque to start against full load, so output is reduced in the start position. The motors are thus normally started under a light load condition.
5. Switching causes a transient current which may have peak values in excess of those with DOL.

Q52 + Q.53. Explain consequent pole starter.

Consequent Pole multi-speed motors having two speeds on a single winding (consequent pole) require a starter which reconnects the motor leads to half the number of effective motor poles at the high speed point. In this type of motor, the low speed is one half the high speed.

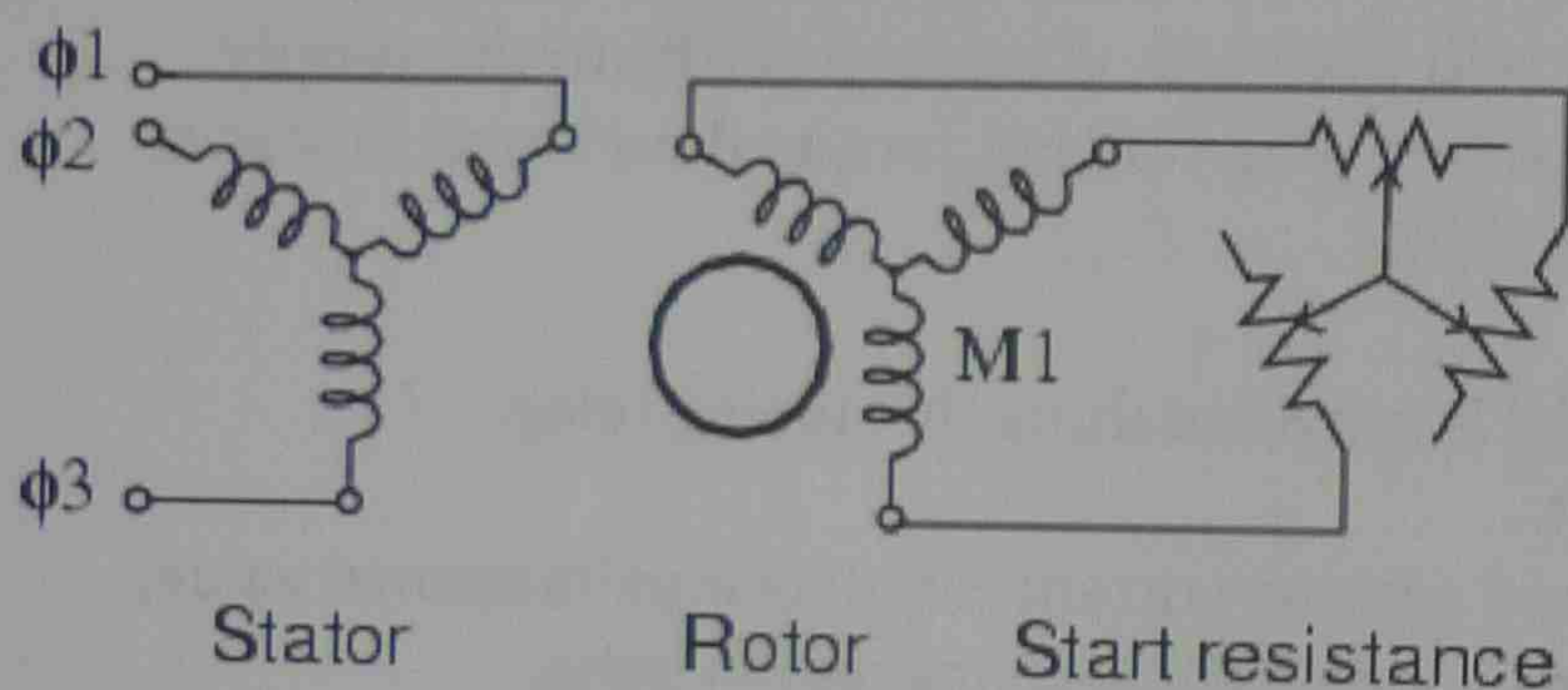
Q54. Explain silicon controlled SCR & it's application in motor speed control with sketches.

The SCR stand for Silicon Control Rectifier, it is used in industries because it can handle high values of current and voltage.

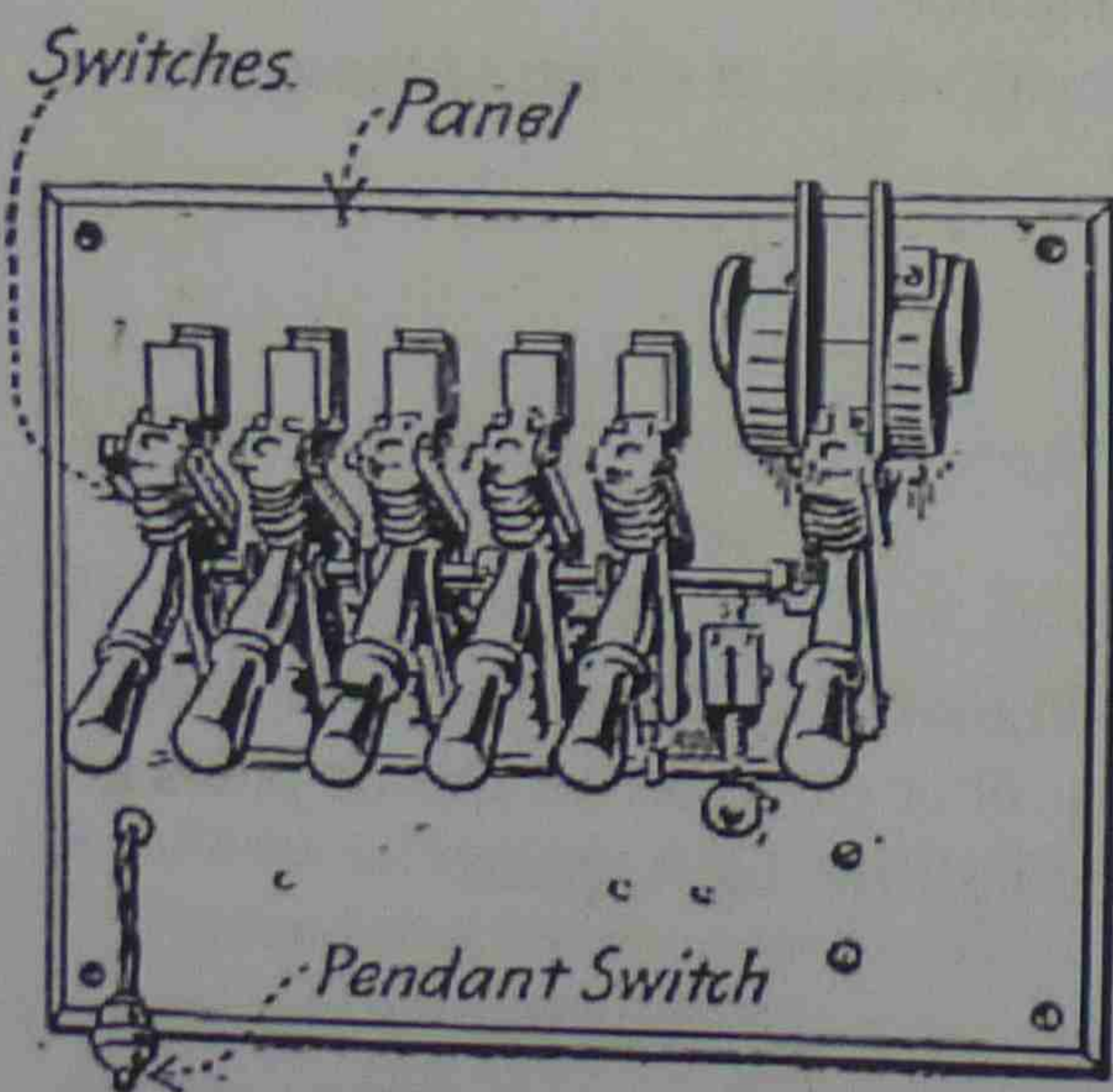


Q55. Explain wound rotor motor.

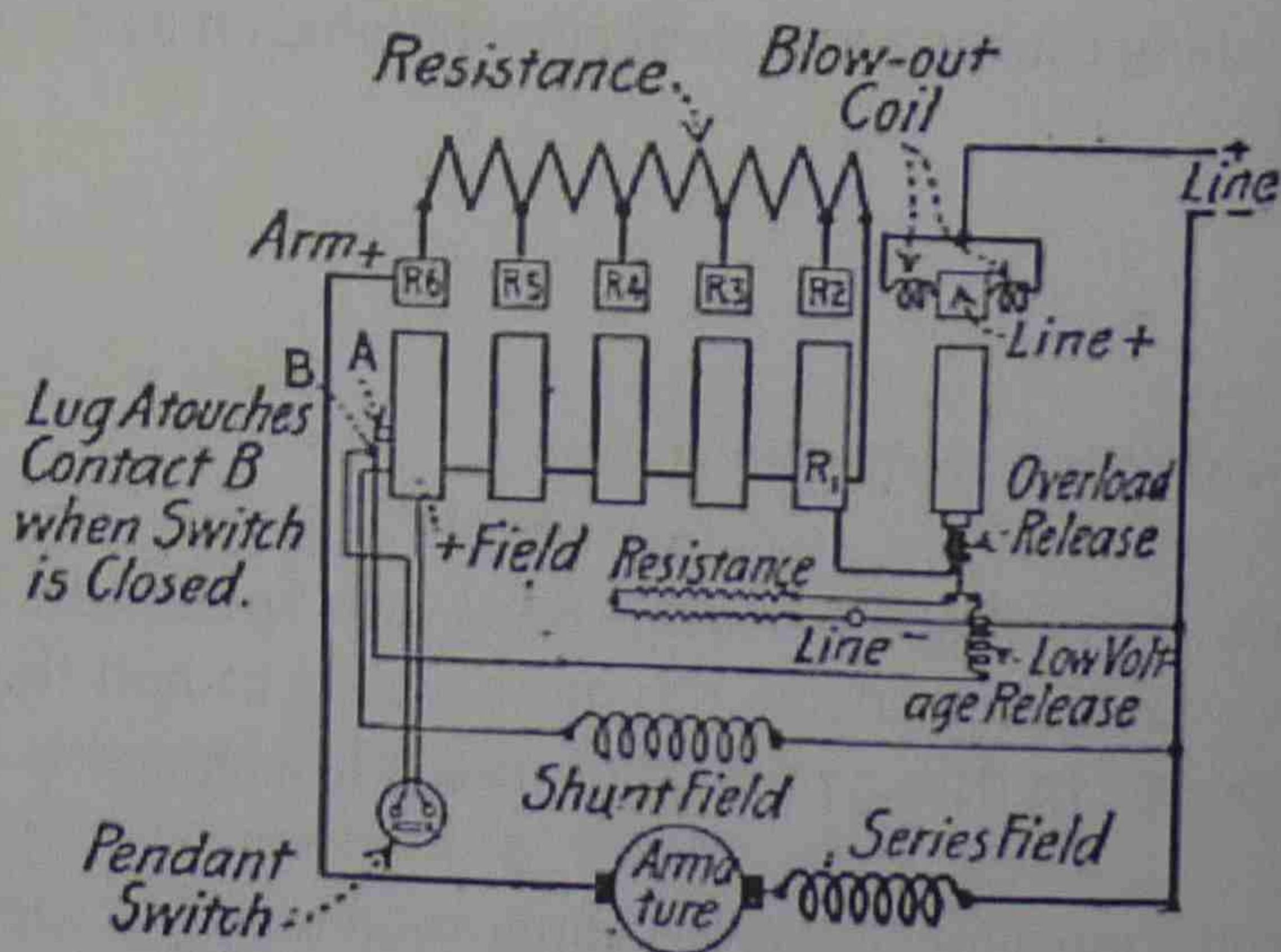
A *wound rotor* induction motor has a stator like the squirrel cage induction motor, but a rotor with insulated windings brought out via slip rings and brushes. However, no power is applied to the slip rings. Their sole purpose is to allow resistance to be placed in series with the rotor windings while starting. This resistance is shorted out once the motor is started to make the rotor look electrically like the squirrel cage counterpart.



Q56. Explain (a) Multi switch starter (b) Drum controller



Front Elevation.



Wiring Diagram.

FIG. 97.—Multi-switch starter (single-pole starter is shown).

starting, resistance is cut out of the armature circuit by closing switches connected between the plus side of the line.

Q57.Explain application of slip ring motor

Slip-ring motors are used in applications requiring high starting torque or low starting current. These motors provide maximum availability, and are especially recommended for heavy load inertia applications like mill drives or situations where network conditions are weak.

Slip-ring motors are of modular construction and have a wide range of accessories. Depending on the application many alternative cooling and enclosure types are available.

Q58.What are advantages and disadvantages of using squirrel cage induction motor?

A squirrel cage motor is less complicated and generally lower priced. A 3-phase squirrel cage motor is self starting. The starting mechanism for a single phase motor is relatively simple. Large squirrel cage motors are less efficient than large synchronous motors. Their operating speed is less than synchronous speed by a "slip" speed that is usually about 2 or 3% at full load and varies in proportion to load.

Synchronous motors operate at exactly synchronous speed regardless of load. They can be adjusted to run at unity or leading power factor. They require starting and excitation control equipment that is more complicated than the starting equipment generally used for squirrel cage motors.

Hysteresis and reluctance motors are self-starting types of synchronous motors. They are used in clocks and in other applications where very small motors are needed with operation at exactly synchronous speed.

Synchronous reluctance motors up to 100 horsepower or so are sometimes used when exact synchronous operation is required. They are more expensive than squirrel cage motors and have a high starting current and low power factor.

Q60.Explain frequency & speed control methods.

A **variable-frequency drive (VFD)** is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor.^{[1][2][3]} A variable frequency drive is a specific type of adjustable-speed drive. Variable-frequency drives are also known as adjustable-frequency drives (AFD), variable-speed drives (VSD), AC drives, microdrives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called **VVVF** (variable voltage variable frequency) drives.

Variable-frequency drives are widely used in ventilation systems for large buildings; variable-frequency motors on fans save energy by allowing the volume of air moved to match the system demand. They are also used on pumps, elevator, conveyor and machine tool drives.

Recent developments in drive electronics have allowed efficient and convenient speed control of these motors, where this has not traditionally been the case. The newest advancements allow for torque generation down to zero speed. This allows the polyphase AC induction motor to compete in areas where DC motors have long dominated, and presents an advantage in robustness of design, cost, and reduced maintenance.

Q61. Explain (a) Multi speed starter (b) Motor protection

Multispeed motor starters: Motor windings in multispeed squirrel-cage motors may require special starters.

a) Starters for separate-winding two-speed motors consist of two standard three-pole starter units that are electrically and mechanically interlocked and mounted in a single enclosure. Additional units can be used for each speed. Although these are always electrically interlocked, it may not be practical to provide mechanical interlocks on more than two starters.

The starter for a consequent-pole two-speed motor requires a three-pole unit and a five-pole unit. The design of the particular motor winding determines whether the fast or slow-speed connection is made by the five-pole unit.

For three-speed consequent-pole motors, a three-pole starter is used for the single-speed winding; a five-pole starter and a second three-pole starter handle the reconnectable winding. A four-speed consequent-pole motor requires two sets of three and five-pole starters.

Different power circuits are needed for delta-type multispeed motors, because currents circulate within the inactive or unconnected winding. A pair of four-pole starters is required for a two-speed motor with separate open-delta windings. Another four-pole starter is required for each speed. Thus, three and four-speed motors with open-delta windings require very complex starters.

Specific winding information is used to select the motor controls. Torque characteristics also deserve special attention to ensure selection of the proper control. Constant-horsepower motors require larger starters than either constant-torque or variable-torque motors of equal horsepower. Reversing and reduced-voltage operations can be incorporated in a multispeed motor starter. **Synchronous motor controls:**

Controllers for synchronous motors have four components: a three-pole starter for the ac stator circuit, a contactor for the dc field circuit, an automatic synchronizing device to control the dc field contactor, and a cage-winding protective relay to open the ac circuit if the motor operates too long without synchronizing.

b) The combination of a circuit-breaker + contactor + thermal relay for the control and protection of motor circuits is eminently appropriate when:

- The maintenance service for an installation is reduced, which is generally the case in tertiary and small and medium sized industrial sites
- The job specification calls for complementary functions

- There is an operational requirement for a load breaking facility in the event of need of maintenance.

Q62. Explain the followings with sketch.

(a) Jogging

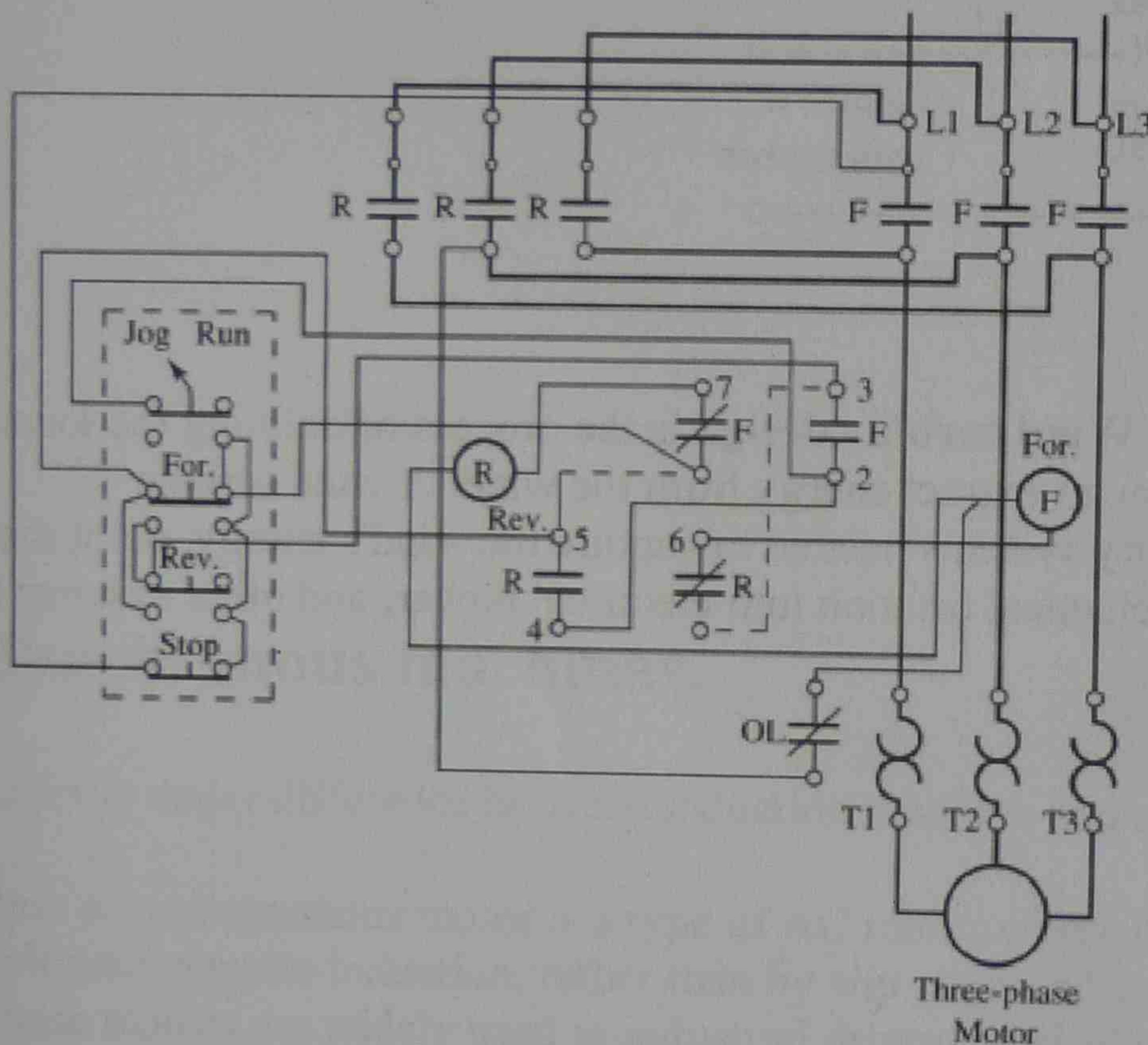
Jogging is moving the motor in small increments. It is mostly used to align or position drive elements for connection or maintenance. If a machine that requires motor jogging for some reason is fitted with a VFD, the VFD may facilitate the jogging but it will still be needed.

There is another operating mode called inching. For very large machines that did not lend themselves to jogging, inching was sometimes used. This was the great grand father of invertors. A DC source would be applied to the motor windings in turn be a series of contactors. The contactors may be controlled by a sequencer or manually by a wheel or crank that operated limit switches that controlled the DC contactors.

Consider a large ball mill (possibly over 20 feet in diameter) that must have an access hatch aligned properly when it is to be removed for internal service of the mill as one possible example.

This system could provide a crude stepped square wave that would cause the motor to rotate slowly and under control.

Although jogging with a VFD may be more analogous to inching than to jogging, inching systems were quite rare and the term jogging is more readily recognized.



(b) Plugging

Braking an electric motor by reversing its connections, so it tends to turn in the opposite direction; the circuit is opened automatically when the motor stops, so the motor does not actually reverse.

(*engineering*) The formation of a barrier (plug) of solid material in a process flow system, such as a pipe or reactor.

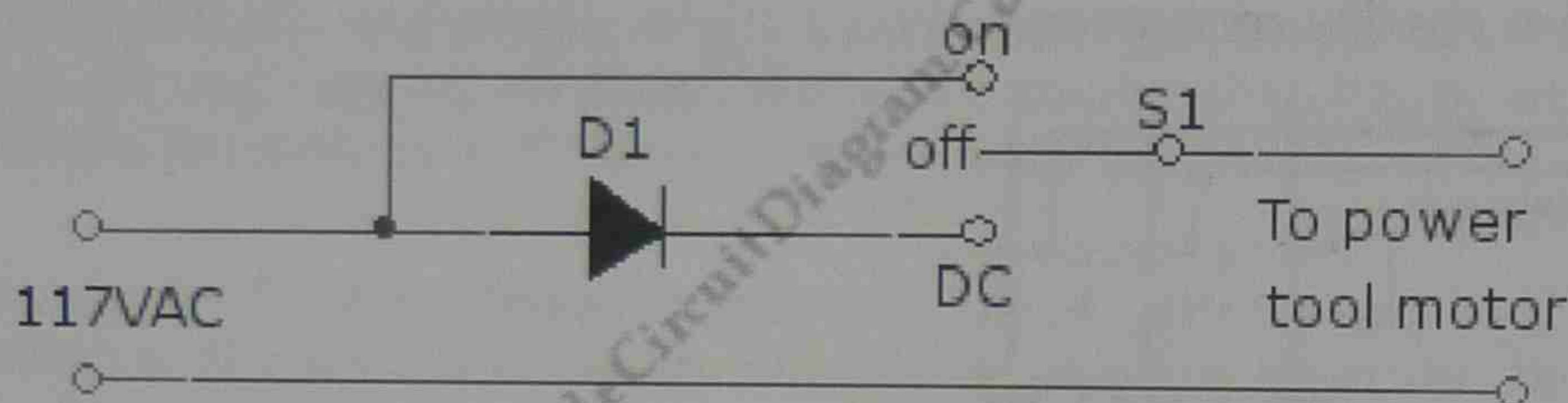
(*petroleum engineering*) The act or process of stopping the flow of water, oil, or gas in strata

penetrated by a borehole or well so that fluid from one stratum will not escape into another or to the surface; especially the sealing up of a well that is dry and is to be abandoned.

c) Braking

Engine braking is where the retarding forces within an engine are used to slow a vehicle down, as opposed to using an external braking mechanism, for example friction brakes or magnetic brakes.

The term is often confused with several other types of braking, most notably compression-release braking or 'jake braking' which uses a different mechanism entirely. Correct use of the term only applies to petrol engines and other engines that throttle air intake.



Q63. Explain mechanical braking: **Wind turbine design** is the process of defining the form and specifications of a wind turbine to extract energy from the wind. A wind turbine installation consists of the necessary systems needed to capture the wind's energy, point the turbine into the wind, convert mechanical rotation into electrical power, and other systems to start, stop, and control the turbine.

G043-Synchronous machines.

Q64.Explain the major difference between induction machine and synchronous machine.

An induction or asynchronous motor is a type of AC motor where power is supplied to the rotor by means of electromagnetic induction, rather than by slip rings and commutators as in slip-ring AC motors. These motors are widely used in industrial drives, particularly polyphase induction motors, because they are robust, have no friction caused by brushes, and their speed can be easily controlled.

In a synchronous AC motor, the rotating magnetic field of the stator imposes a torque on the magnetic field of the rotor, causing it to rotate steadily. It is called synchronous because at steady state, the speed of the rotor matches the speed of the rotating magnetic field in the stator. By contrast, an induction motor has a current induced in the rotor; to do this, stator windings are arranged so that when energised with a polyphase supply they create a rotating magnetic field that induces current in the rotor conductors. These currents interact with the rotating magnetic field, causing rotational motion of the rotor.

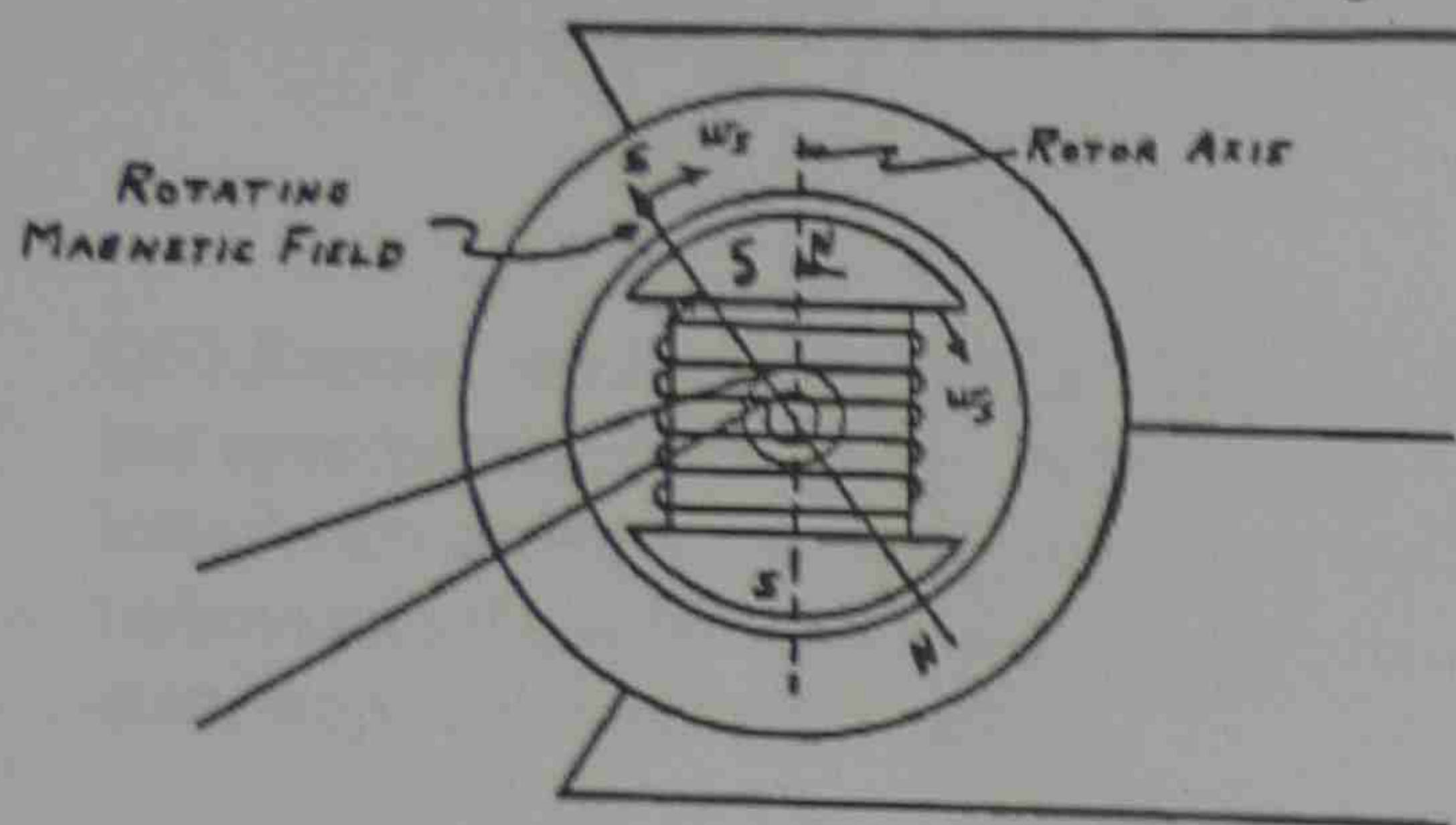
Q65. Explain the construction of synchronous machine

A **synchronous electric motor** is an AC motor distinguished by a rotor spinning with coils passing magnets at the same rate as the power supply frequency and resulting rotating magnetic field which drives it.

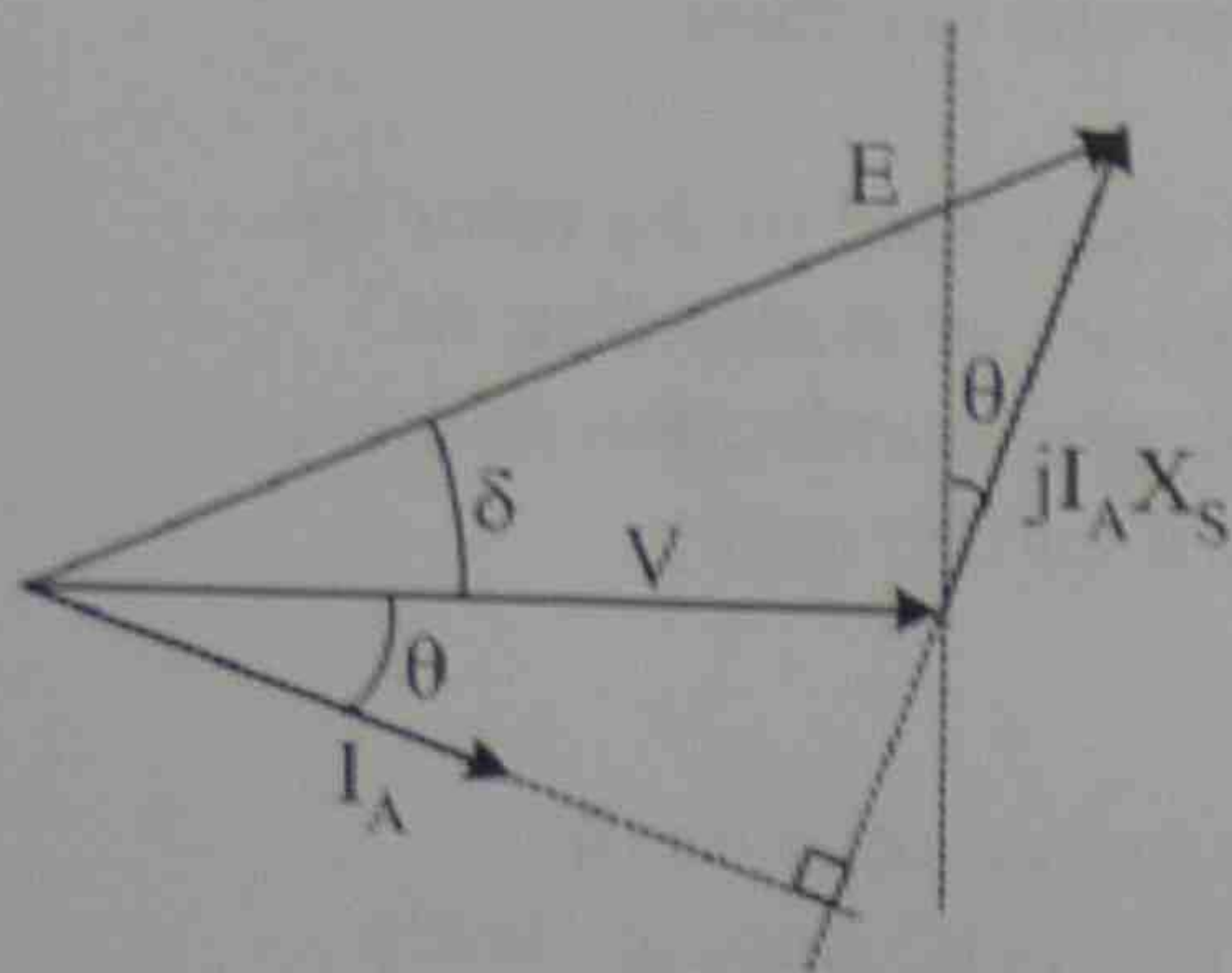
Another way of saying this is that it does not rely on slip under usual operating conditions and as a result, produces torque at synchronous speed. Synchronous motors can be contrasted with an induction motor, which must slip in order to produce torque. They operate synchronously with line frequency. As with squirrel-cage induction motors, speed is determined by the number of pairs of poles and the line frequency.

Synchronous motors are available in sub-fractional **self-excited** sizes to high-horsepower **direct-current excited** industrial sizes. In the fractional horsepower range, most synchronous motors are used where precise constant speed is required. In high-horsepower industrial sizes, the synchronous motor provides two important functions. First, it is a highly efficient means of converting ac energy to work. Second, it can operate at leading or unity power factor and thereby provide power-factor correction.

Q66. Sketch the equivalent circuit, vector diagram and write the voltage equation for synchronous



generator.



$$V_{\text{phase}} = E_a - jX_s I_a - R_a I_a$$

where: $X_s = X_{ad} + X_l$

$$X_{ad} = (E_f + R_a I_q + X_d I_d) / I_{fd}$$

Sketch the circuit, vector diagram and write the voltage equation for synchronous motor.



3 Synchronous Generator Operation

3.1 Cylindrical Rotor Machine

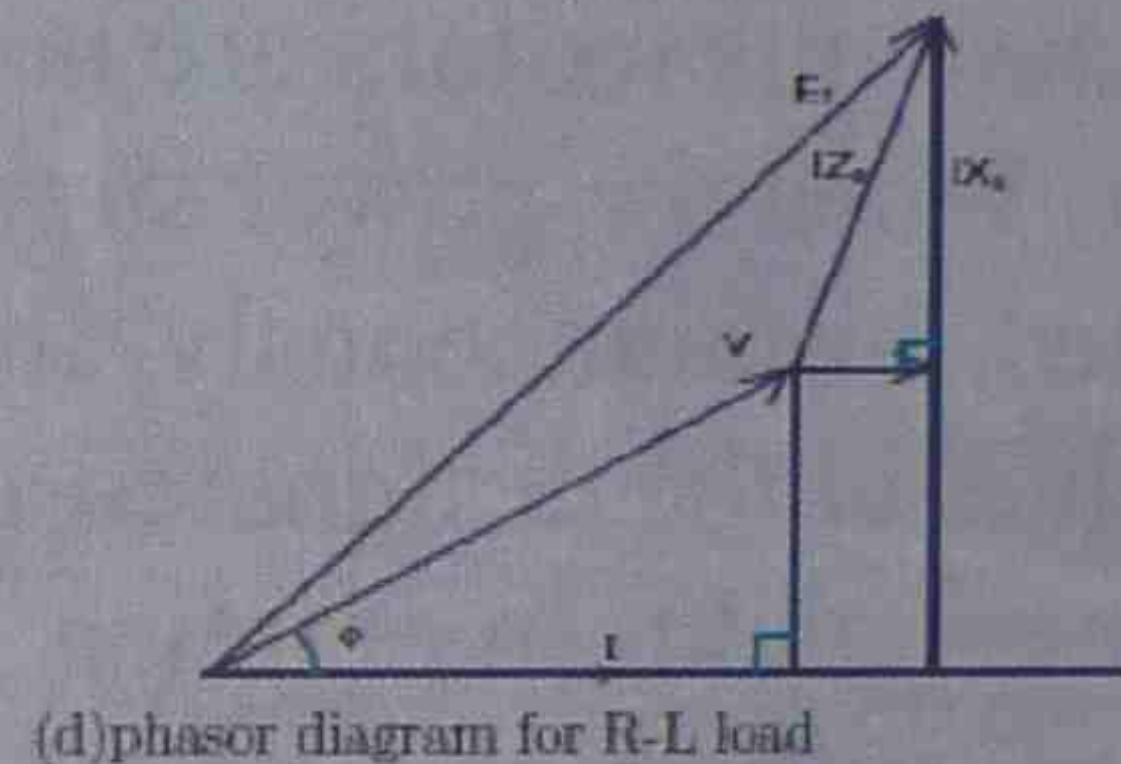
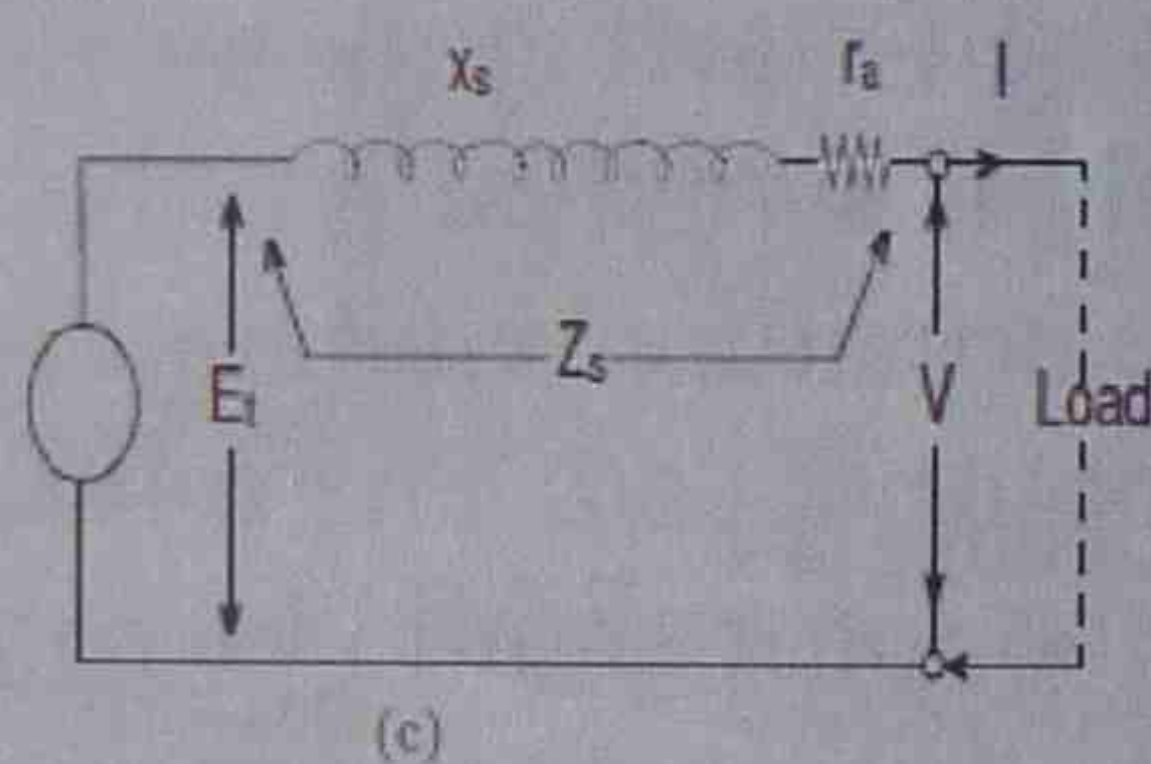
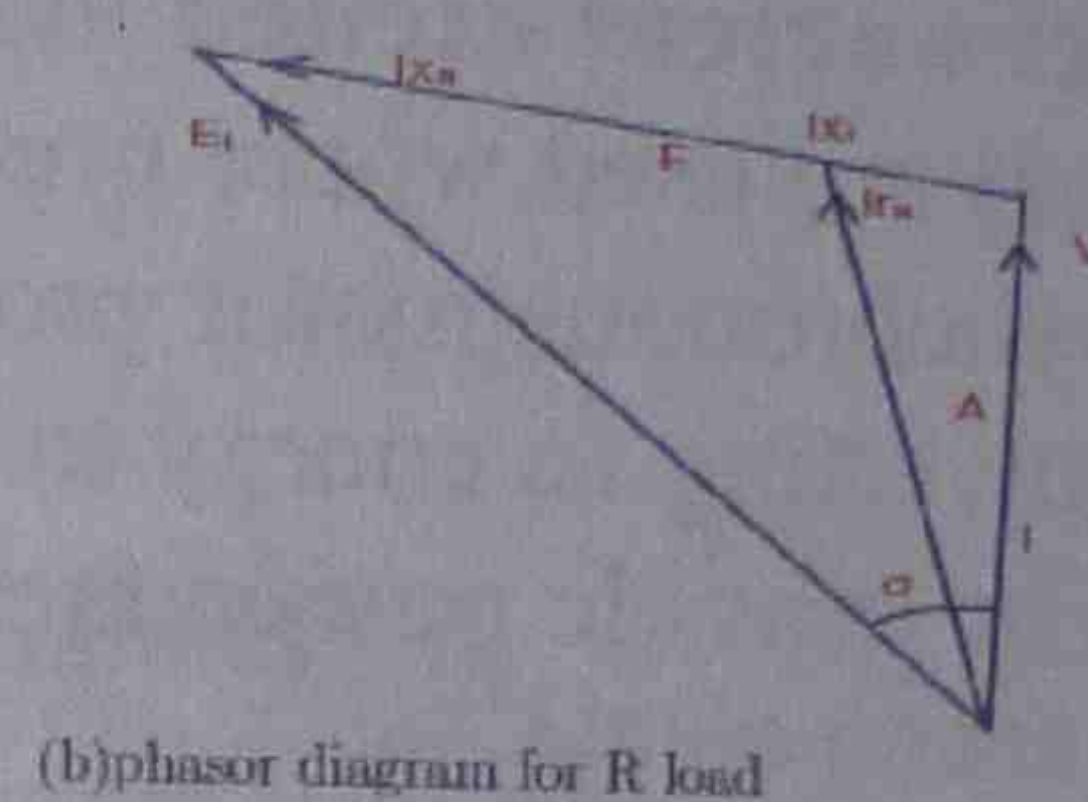
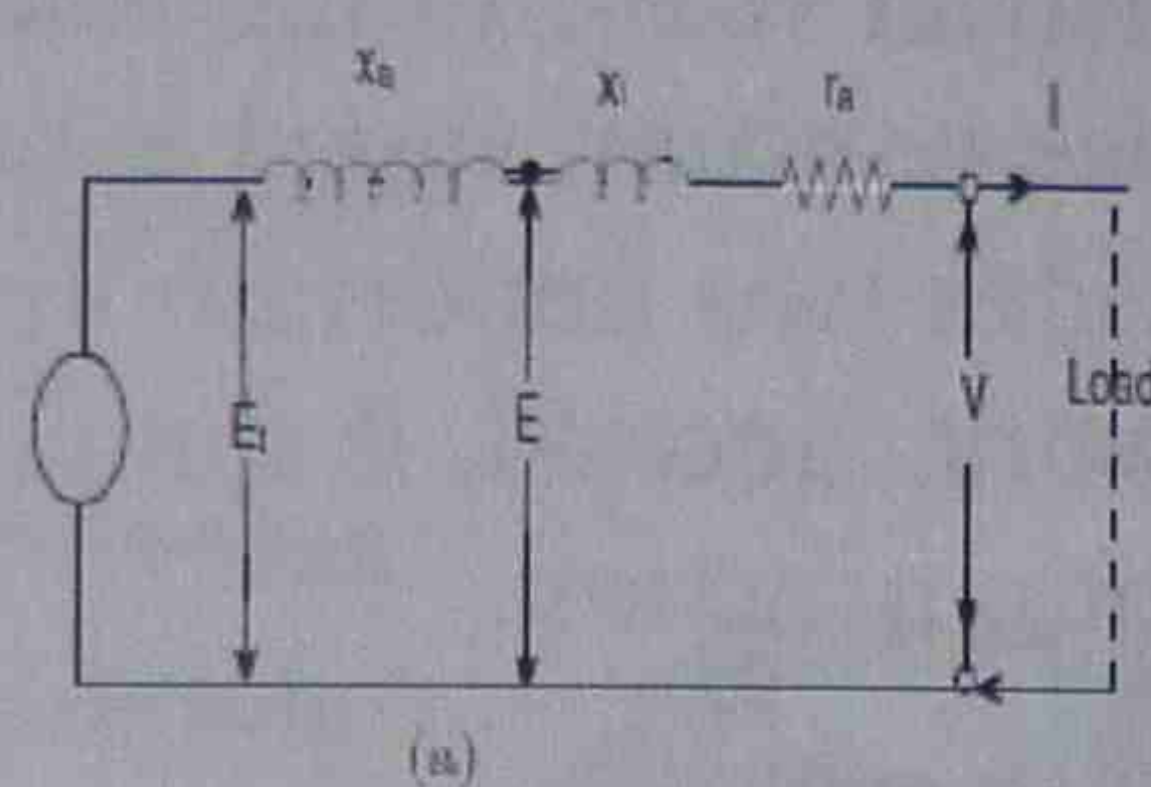


Figure 30: Equivalent circuits

The synchronous generator, under the assumption of constant synchronous reactance, may be considered as representable by an equivalent circuit comprising an ideal winding in which an e.m.f. E_t proportional to the field excitation is developed, the winding being connected to the terminals of the machine through a resistance r_a and reactance

Q68.Explain the effect of field excitation on power factor of synchronous motor.

A **synchronous electric motor** is an AC motor distinguished by a rotor spinning with coils passing magnets at the same rate as the power supply frequency and resulting rotating magnetic field which drives it.

Another way of saying this is that it does not rely on slip under usual operating conditions and as a result, produces torque at synchronous speed. Synchronous motors can be contrasted with an induction motor, which must slip in order to produce torque. They operate synchronously with line frequency. As with squirrel-cage induction motors, speed is determined by the number of pairs of poles and the line frequency.

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Q74.Explain starting methods for synchronous motor.

Synchronous motors are not self-starting motors. This property is due to the inertia of the rotor. When the power supply is switched on, the armature winding and field windings are excited. Instantaneously, the armature winding creates a rotating magnetic field, which revolves at the designated motor speed. The rotor, due to inertia, will not follow the revolving magnetic field. In practice, the rotor should be rotated by some other means near to the motor's synchronous speed to overcome the inertia. Once the rotor nears the synchronous speed, the field winding is excited, and the motor pulls into synchronization.

The following techniques are employed to start a synchronous motor:

- A separate motor (called pony motor) is used to drive the rotor before it locks in into synchronization.
- The field winding is shunted or induction motor like arrangements are made so that the synchronous motor starts as an induction motor and locks in to synchronization once it reaches speeds near its synchronous speed.
- Reducing the input electrical frequency to get the motor starting slowly, variable-frequency drives can be used here which have rectifier-inverter circuits or cycloconverter circuits.

Q75.Compare synchronous motor & induction motor.

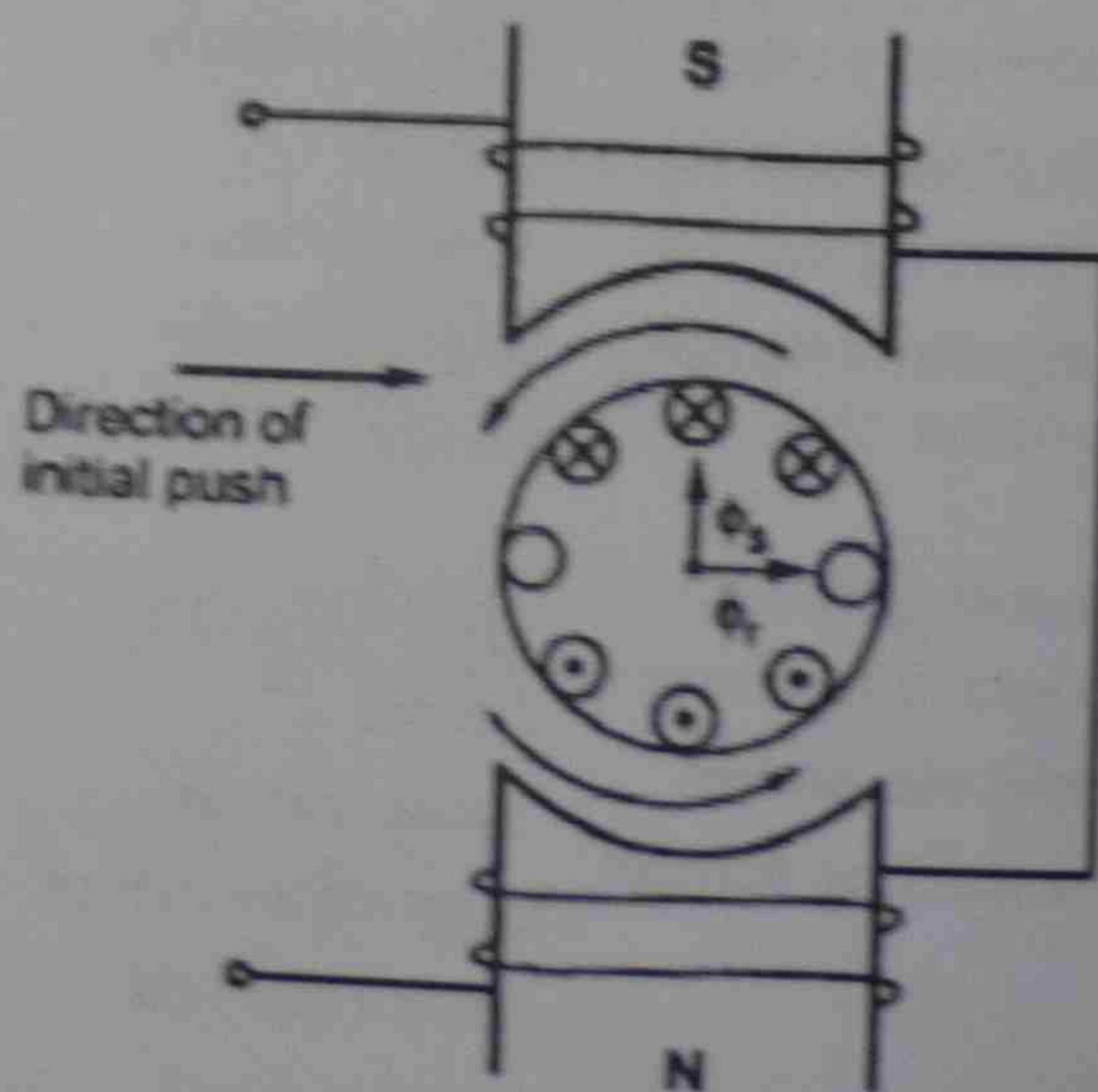
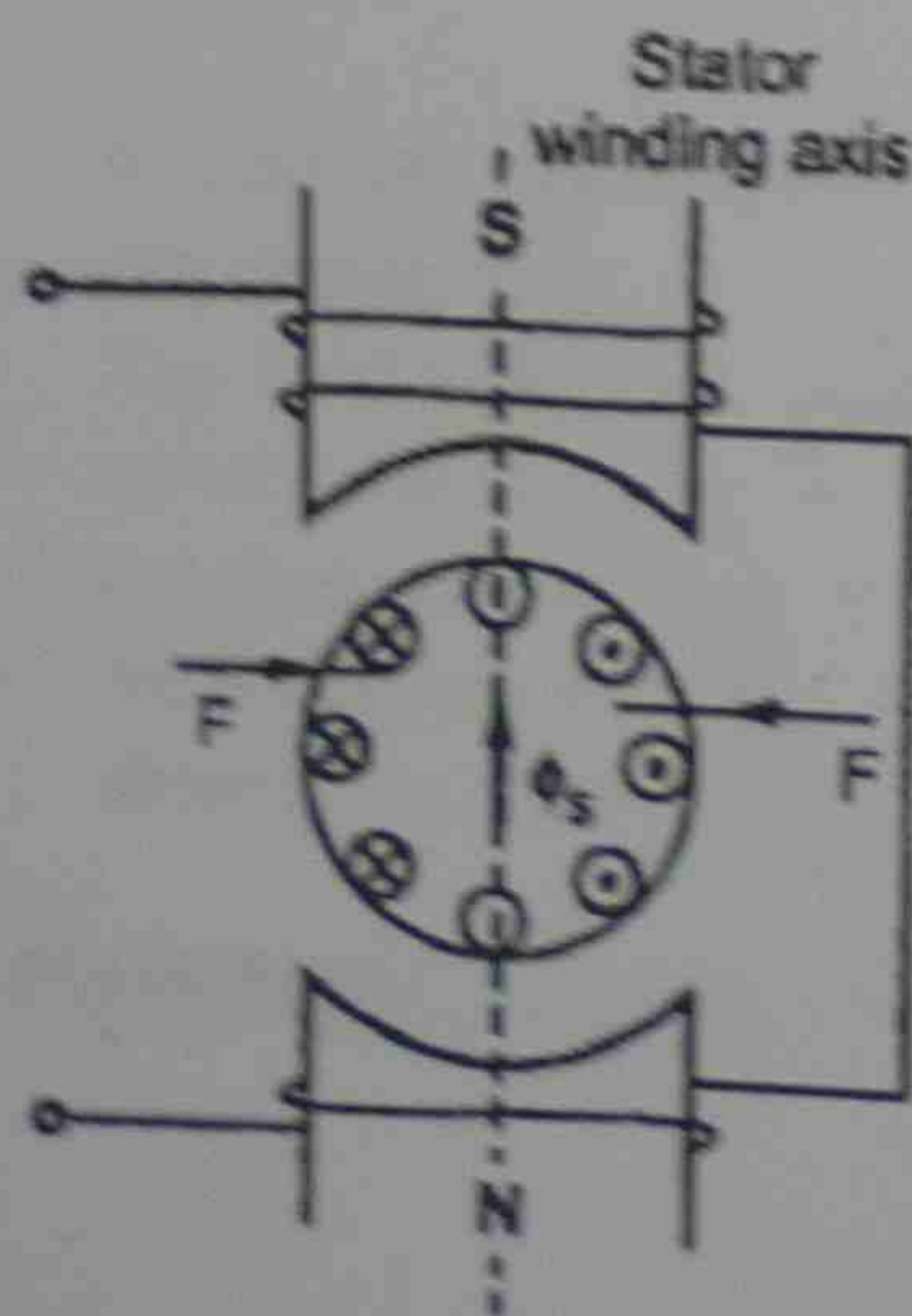
Comparison

Comparison of motor types^[22]

Type	Advantages	Disadvantages	Typical Application	Typical Drive
AC polyphase induction squirrel-cage	Low cost, long life, high efficiency, large ratings available (to 1 MW or more), large number of standardized types	Starting inrush current can be high, speed control requires variable frequency source	Pumps, fans, blowers, conveyors, compressors	Poly-phase AC, variable frequency AC
<u>Shaded-pole motor</u>	Low cost Long life	Speed slightly below synchronous Low starting torque Small ratings low efficiency	Fans, appliances, record players	Single phase AC
AC induction – Squirrel cage, split-phase capacitor-start	High power high starting torque	Speed slightly below synchronous Starting switch or relay required	Appliances Stationary Power Tools	Single phase AC
AC induction – Squirrel cage, split-phase capacitor-run	Moderate power High starting torque No starting switch Comparatively long life	Speed slightly below synchronous Slightly more costly	Industrial blowers Industrial machinery	Single phase AC
AC induction – Squirrel cage motor, split-phase, auxiliary start winding	Moderate power Low starting torque	Speed slightly below synchronous Starting switch or relay required	Appliances Stationary Power Tools	Single phase AC
<u>Universal motor</u>	High starting torque, compact, high speed,	Maintenance (brushes)	Handheld power tools, blenders,	Single phase AC

	usually acoustically noisy	Shorter lifespan Only small ratings are economic	vacuum cleaners, insulation blowers	or DC
<u>AC Synchronous</u>	Synchronous speed	More costly	Industrial motors Clocks Audio turntables Tape drives	Single or Polyphase AC (Capacitor-run for single-phase)
<u>Stepper DC</u>	Precision positioning High holding torque	Some can be costly Require a controller	Positioning in printers and floppy disc drives; industrial machine tools	DC
<u>Brushless DC</u>	Long lifespan Low maintenance High efficiency	Higher initial cost Requires a controller	Rigid ("hard") disk drives CD/DVD players Electric vehicles RC Vehicles UAVs	DC or <u>PWM</u>

Q76. Explain (a) cross field theory (b) rotating field theory of single phase motor.



Assume now that an initial push is given to the rotor anticlockwise direction. Due to the rotation, rotor physically cuts the stator flux and dynamically e.m.f. gets induced in the rotor. This is called speed e.m.f. or rotational e.m.f. The direction of such e.m.f. can be obtained by Fleming's right hand rule and this e.m.f. is in phase with the stator flux Φ_s . The direction of e.m.f. is shown in the Fig. 2. This e.m.f. is denoted as E_{2N} . This e.m.f. circulates current through rotor which is I_{2N} . This current produces its own flux called rotor flux Φ_r . This axis of Φ_r is at 90° to the axis of stator flux hence this rotor flux is called cross-field.

These are small motors having an output power less than one horse power and are generally operated on single phase AC supply. These motors perform varieties of service in the home, office, business concerns, factories and farms and in a number of other applications where single phase supply is available.

Single phase motor is not self-starting. Hence, it is provided with an extra winding known as auxiliary or starting winding in addition to main or running winding. These two windings are spaced 90° electrically apart and are put in parallel, so that a rotating field is produced.

Q77. Explain the control of electric generating system.

Electricity generation is the process of generating electric energy from other forms of energy.

The fundamental principles of electricity generation were discovered during the 1820s and early 1830s by the British scientist Michael Faraday. His basic method is still used today: electricity is generated by the movement of a loop of wire, or disc of copper between the poles of a magnet.

For electric utilities, it is the first process in the delivery of electricity to consumers. The other processes, electricity transmission, distribution, and electrical power storage and recovery using pumped storage methods are normally carried out by the electric power industry.

Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. There are many other technologies that can be and are used to generate electricity such as solar photovoltaics and geothermal power.

Q78. Explain voltage regulator.

A **voltage regulator** is an electrical regulator designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

Electronic voltage regulators are found in devices such as computer power supplies where they stabilize the DC voltages used by the processor and other elements. In automobile alternators and central power station generator plants, voltage regulators control the output of the plant. In an electric power distribution system, voltage regulators may be installed at a substation or along distribution lines so that all customers receive steady voltage independent of how much power is drawn from the line.

Q79.Explain prime mover & governor.

A **centrifugal governor** is a specific type of governor that controls the speed of an engine by regulating the amount of fuel (or working fluid) admitted, so as to maintain a near constant speed whatever the load or fuel supply conditions. It uses the principle of proportional control.

It is most obviously seen on steam engines where it regulates the admission of steam into the cylinder(s). It is also found on internal combustion engines and variously fueled turbines, and in some modern striking clocks.

Q80.Explain the types of excitations.

An electric generator or electric motor that uses field coils rather than permanent magnets requires a current to be present in the field coils for the device to be able to work. If the field coils are not powered, the rotor in a generator can spin without producing any usable electrical energy, while the rotor of a motor may not spin at all.

Smaller generators are sometimes self-excited, which means the field coils are powered by the current produced by the generator itself. The field coils are connected in series or parallel with the armature winding. When the generator first starts to turn, the small amount of remanent magnetism present in the iron core provides a magnetic field to get it started, generating a small current in the armature. This flows through the field coils, creating a larger magnetic field which generates a larger armature current. This "bootstrap" process continues until the magnetic field in the core levels off due to saturation and the generator reaches a steady state power output.

Very large power station generators often utilize a separate smaller generator to excite the field coils of the larger. In the event of a severe widespread power outage where islanding of power stations has occurred, the stations may need to perform a black start to excite the fields of their largest generators, in order to restore customer power service.

Q81.How will you select the regulator to control generator voltage?

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Q82. What are the factors affecting voltage stability of generator system?

The image shows a screenshot of a presentation slide displayed in a Mozilla Firefox browser window. The browser's address bar shows the URL: http://www.sari-energy.org/PageFiles/Vihet_Wie_De/activities/CEB_Power_Systems_Simulation_Training_Colombo_Sri_Lanka/Course_ppts/lecture_42.pdf. The slide content is as follows:

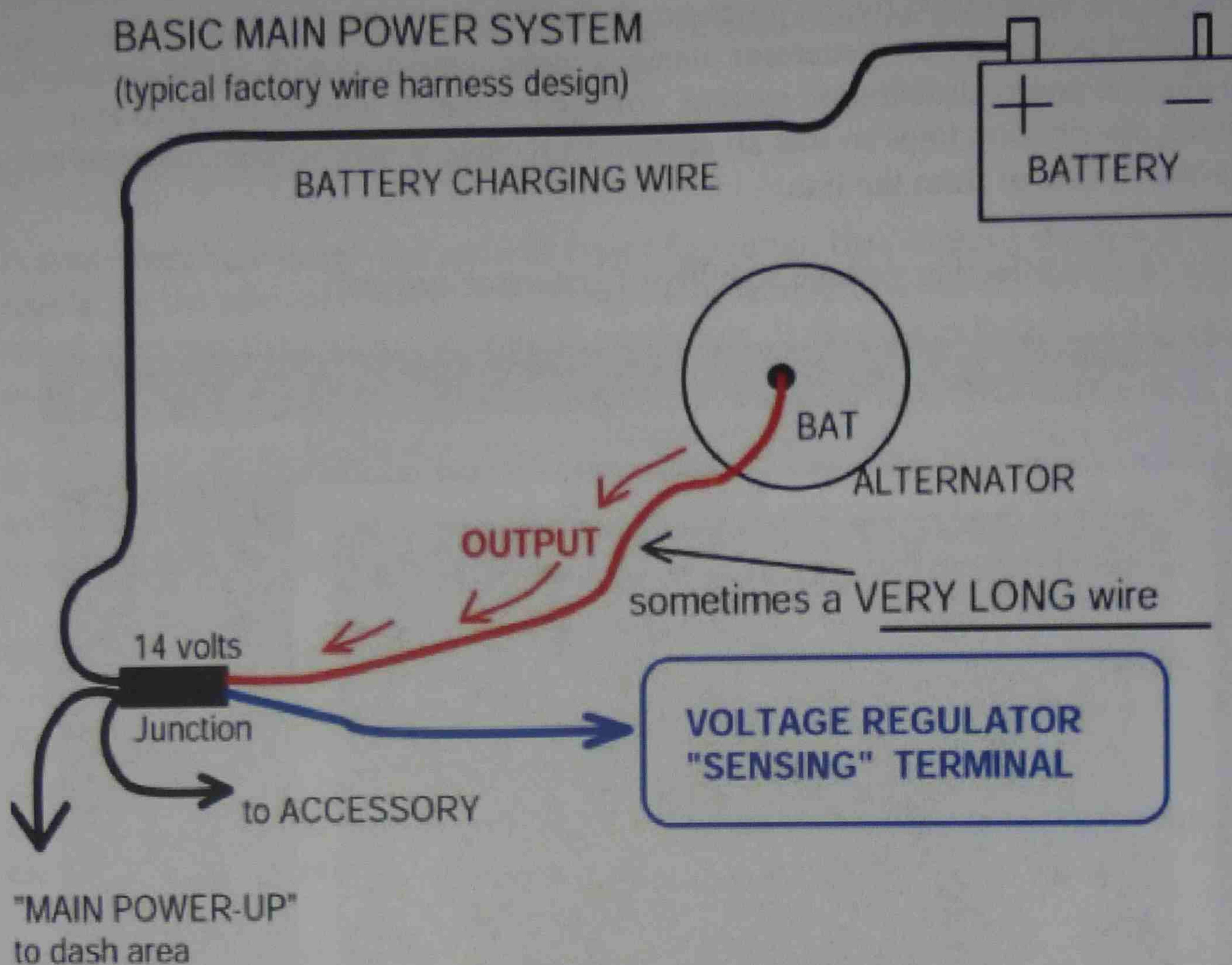
Voltage Collapse

- Following voltage instability, a power system undergoes voltage collapse if the post disturbance equilibrium voltages near load are below acceptable limits.
- Voltage collapse may be total (blackout) or partial.
- The voltage instability and collapse may occur in a time frame of fraction of a second.
- In this case the term 'transient voltage stability' is used. Sometimes, it may take up to tens of minutes in which case the term 'long-term voltage stability' is used.

Factors Affecting Voltage Instability and Collapse

- The voltage collapse occurs invariably following a large disturbance or large load increase in a heavily stressed power system.
- This results in an increased reactive power consumption and voltage drop.
- The voltage drop causes initial load reduction triggering control mechanisms for load restoration. It is the dynamics of these controls that often lead to voltage instability and collapse.

The screenshot also shows the Windows taskbar at the bottom with various application icons and a system clock indicating 10:03 PM on 13/09/2011.



Q84.Explain typical generator instability problem.

AS PER QUESTION 82.

Q85.Explain digital excitation system.

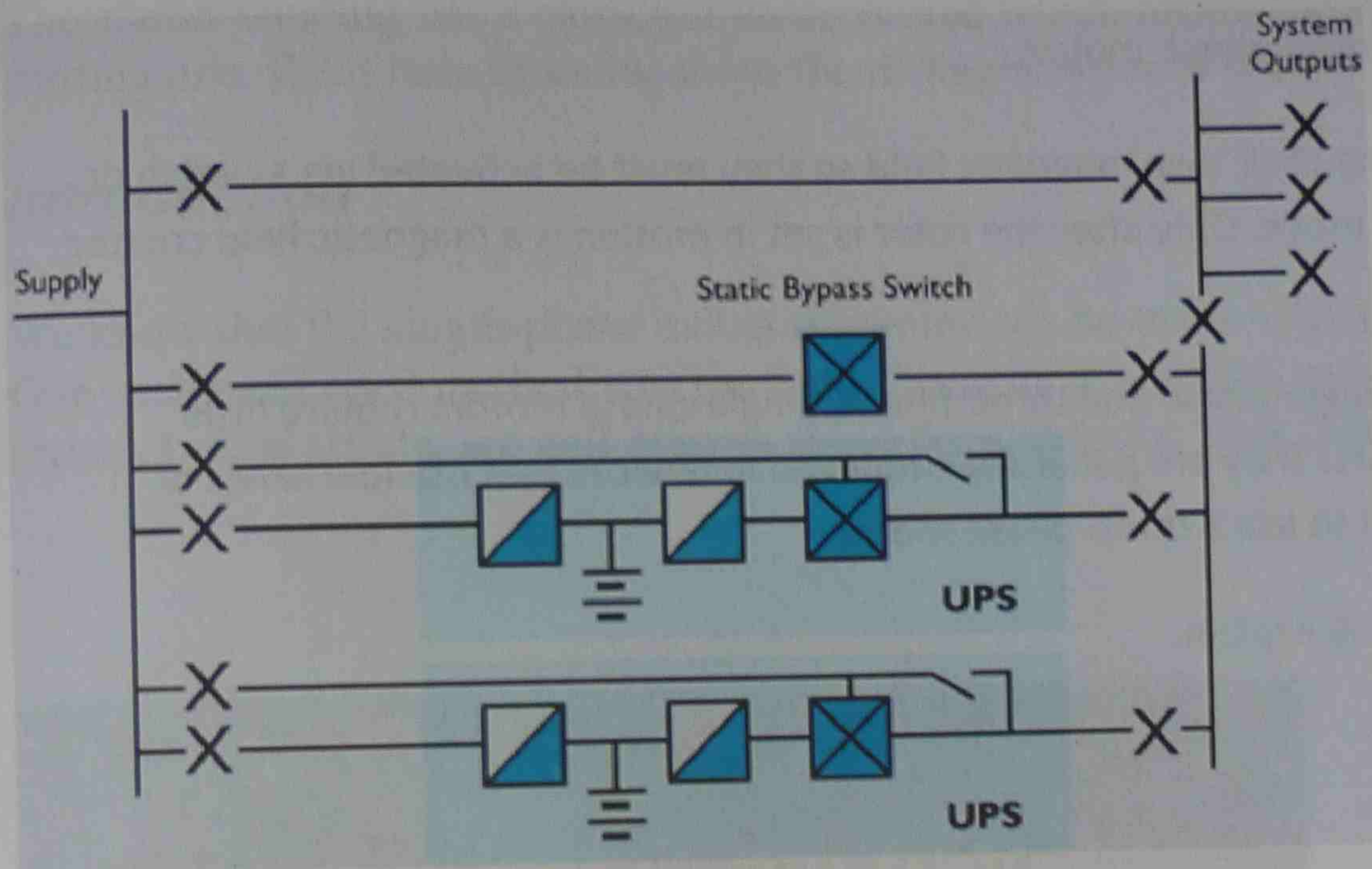
AS a result of the increasing capacity and expansion in operating area of power system, together with the increasing constant power load, there is a tendency for both power stability and voltage stability to decline in power system, and this decline has become a pressing issue. Concerning power stability, in particular, the suppression of the 0.3- to 0.5-Hz longperiod power perturbation that occurs between power systems is being examined closely as a problem that should be solved, in addition to the 1.0 Hz perturbation that occurs between conventional generators. Here, we describe the latest digital exciter system for generator control that is particularly effective in improving system stability.

POWER SYSTEM STABILITY AND EXCITER CONTROL

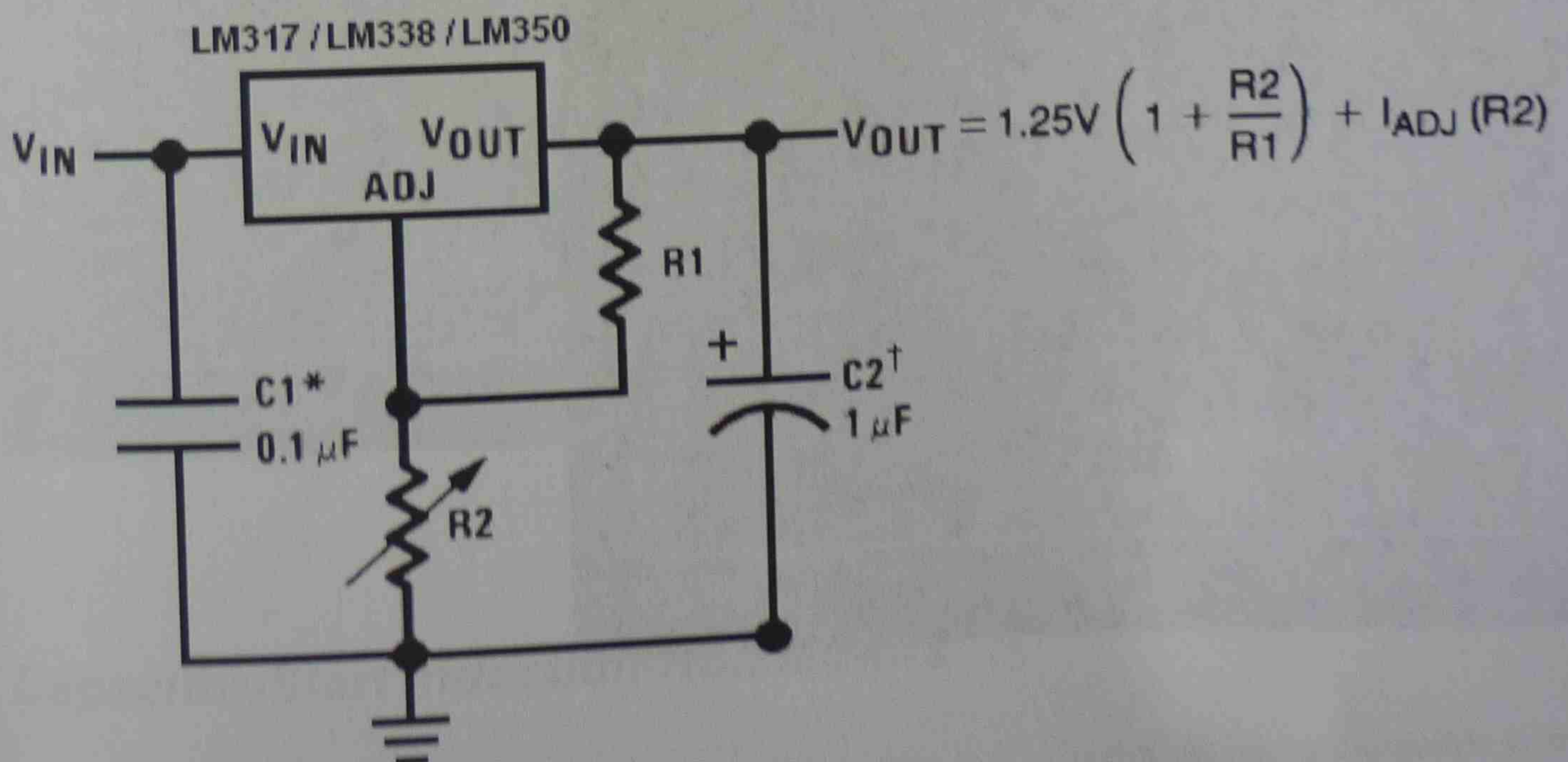
Power system stability involves, voltage stability, in which a constant voltage can be restored and maintained even when changes in load occur, and power stability, in which the power perturbation that arises between generators that are operating in parallel is quickly suppressed and a constant power can be maintained. It is necessary to sufficiently guarantee both types of stability, taking the most severe operating conditions into consideration. The approaches to improving power system

stability include methods of improving the main circuits by increasing the system voltage, construction of additional power transmission lines, installation of series capacitors, installation of SVC (static VAR compensator) and so on and the method of generator exciter control. Although the main circuit improvement approach is a fundamental measure, the scale of reconstruction is very large. The control approach, on the other hand, makes it possible to extract the maximum capability of the generator by improving the control algorithm when digital control equipment is used, which has a very large economical effect.

Q86. Sketch generator parallel control system.



Q87. Explain digital voltage regulation system.



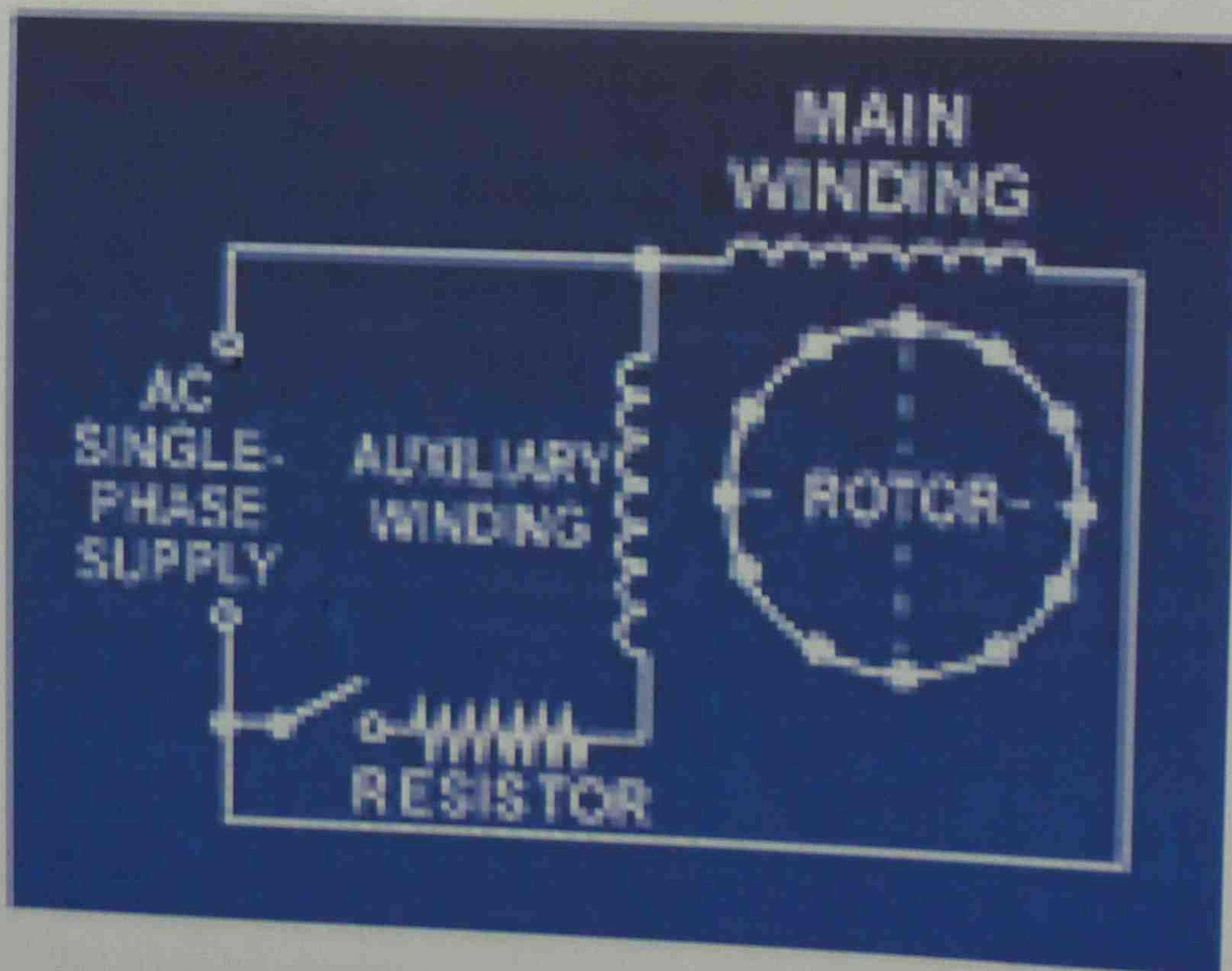
As the automatic voltage regulator (AVR), which regulates generator voltage, is a device indispensable for operation, it is required to have superior reliability in addition to easy maintenance or repair features. And, recently there exists an ever-increasing demand for improved system stability through the excitation control (AVR) in order to prevent decline in system stability in line with the increase in power system and power re-routing. At the same time, digital devices as represented by micro-processors, have been making a remarkable progress.

Q88.Explain the features of single phase motor.

Single-phase motors do not create their own magnetic field so they must be activated via a switch or other device to make their rotor move. Only after the rotor is set in motion is a magnetic field created, thus making it operate.

There are two types of motors: single-phase and three-phase. Single-phase motors require little maintenance and can last for years. They are generally employed in devices that use low levels of horsepower where it is inefficient to use a three-phase motor.

Q89.Sketch capacitor start motor & explain.



Learn about "Capacitor Start - Induction Run" Motors

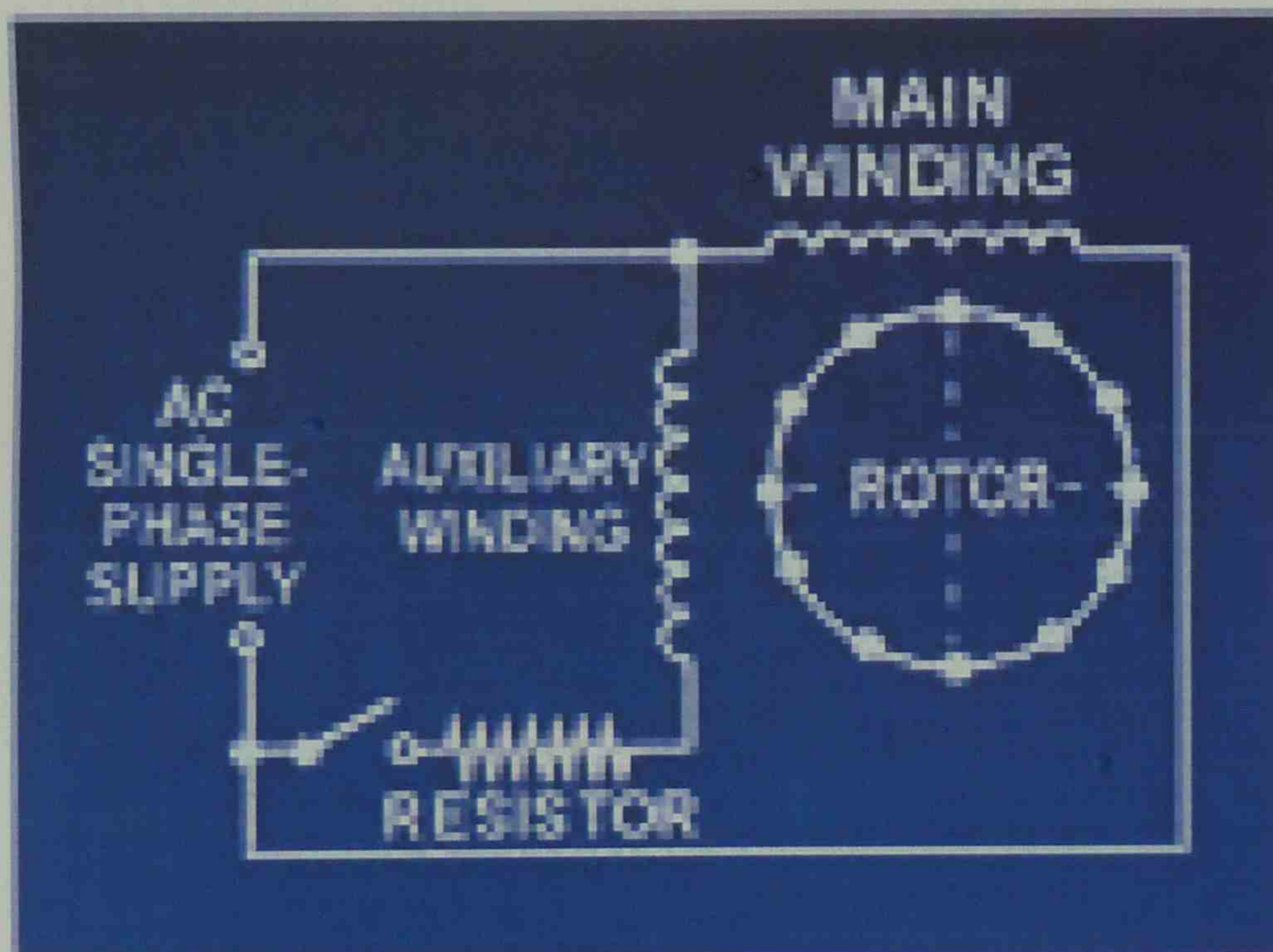
Written by: [sriram balu](#) • Edited by: [KennethSleight](#)

Published Aug 7, 2009

The starter winding has a capacitor incorporated which makes the single-phase motor a self-starting one. Read here to know about the different types of widely used capacitor-motors

Introduction

We know that the single-phase induction motor can be made self-starting in numerous ways. One such most used method was the [Split Phase motors](#) which we discussed in my last article. In this article, we will discuss about the Capacitor Start Induction Run Motors.



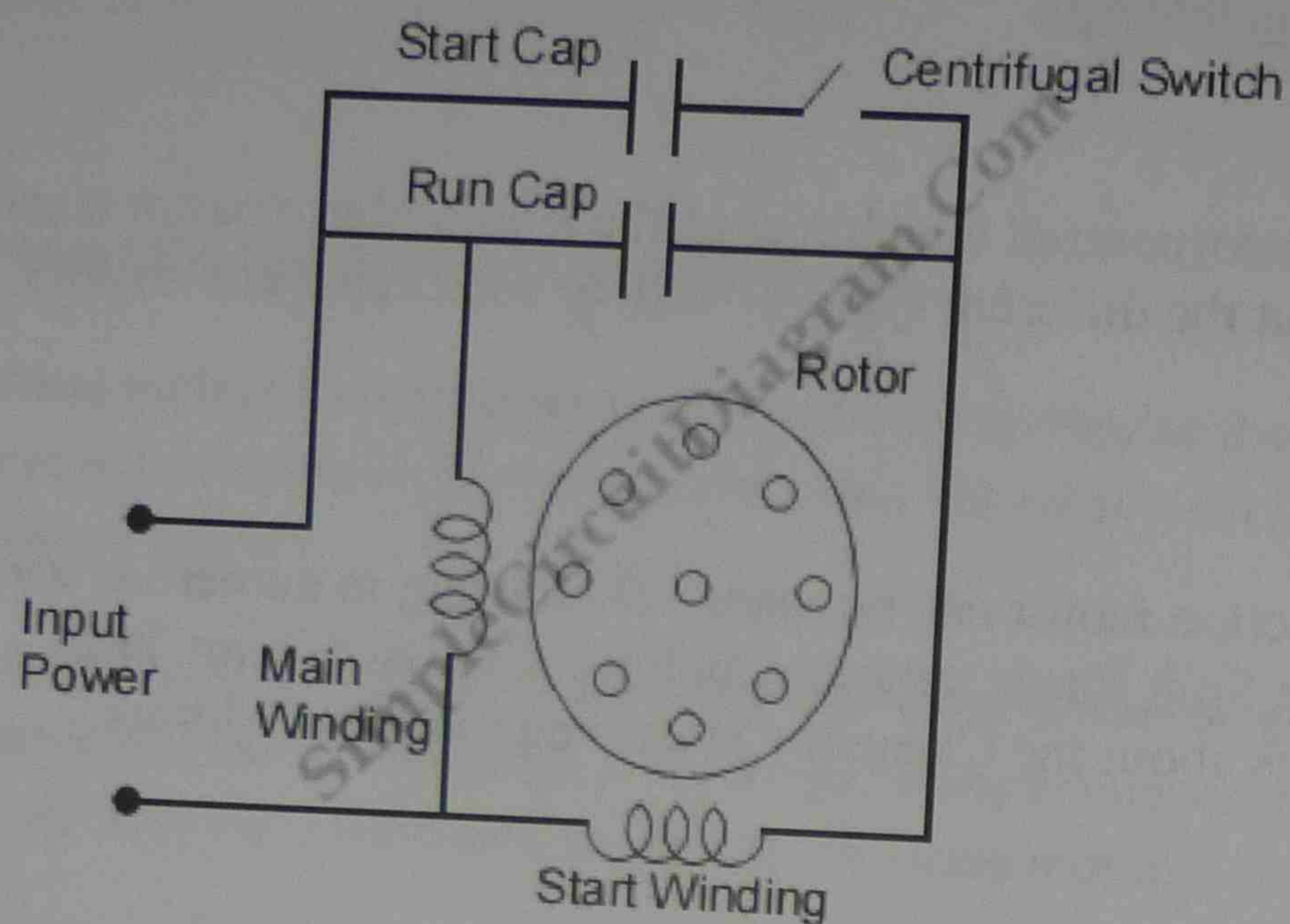
Capacitor-Start Induction-Run Motors

We know about the activity of a capacitor in a pure A.C. Circuit. When a capacitor is so introduced, the voltage lags the current by some phase angle. In these motors, the necessary

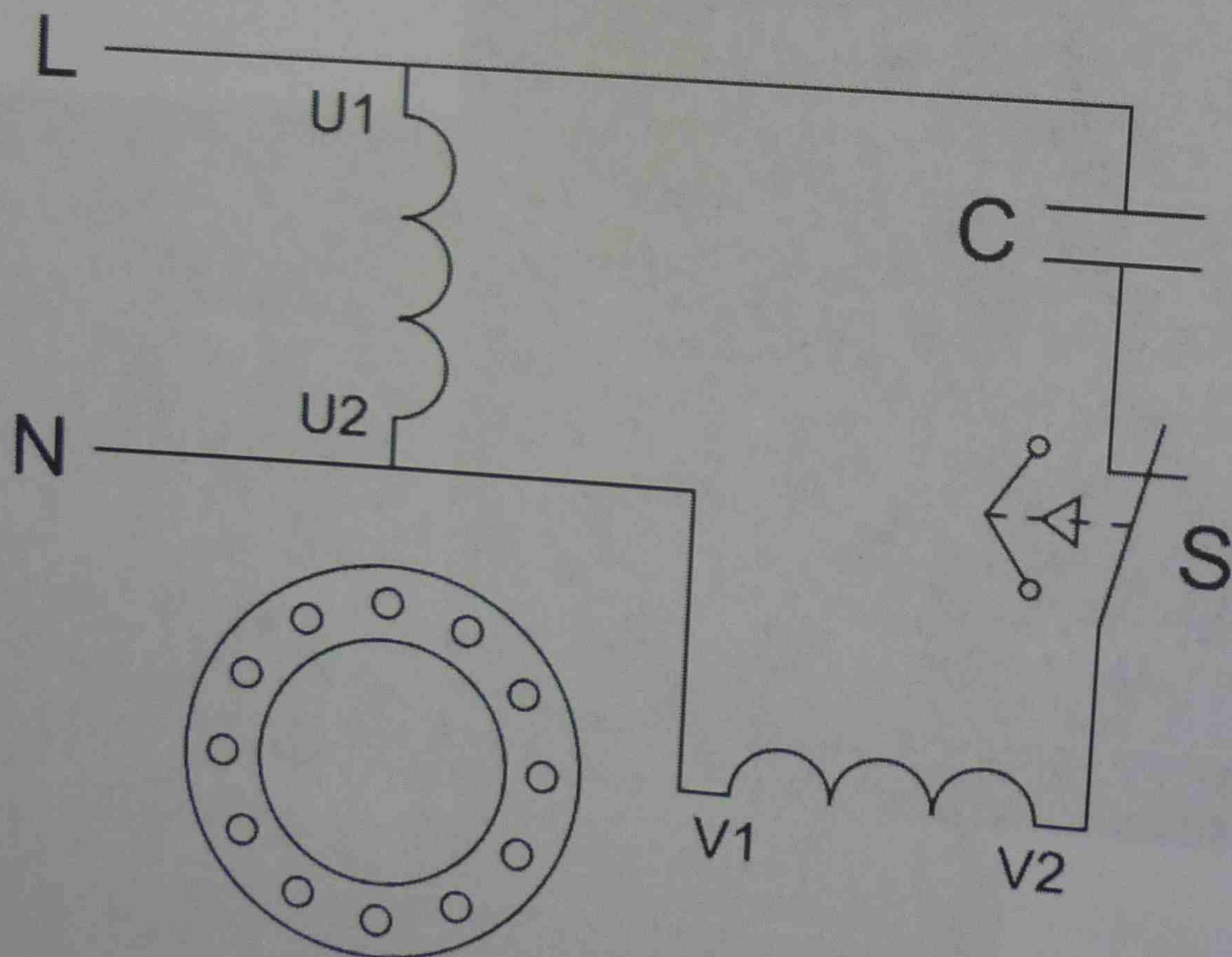
phase difference between the I_s and I_m is obtained by introducing a capacitor in series with the starter winding. The capacitor used in these motors are of electrolytic type and usually visible as it is mounted outside the motor as a separate unit.

Q90. Sketch

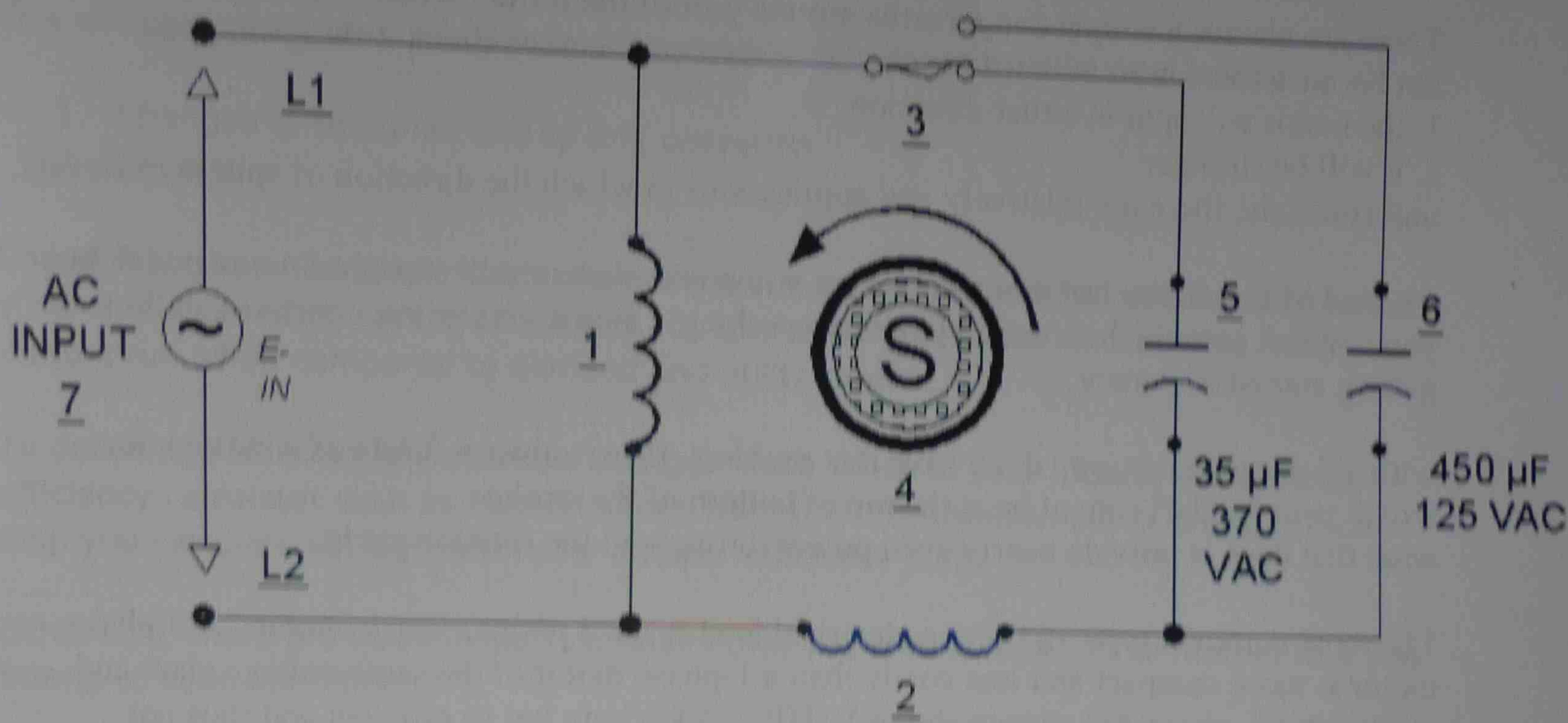
(a) Capacitor start / capacitor run motor



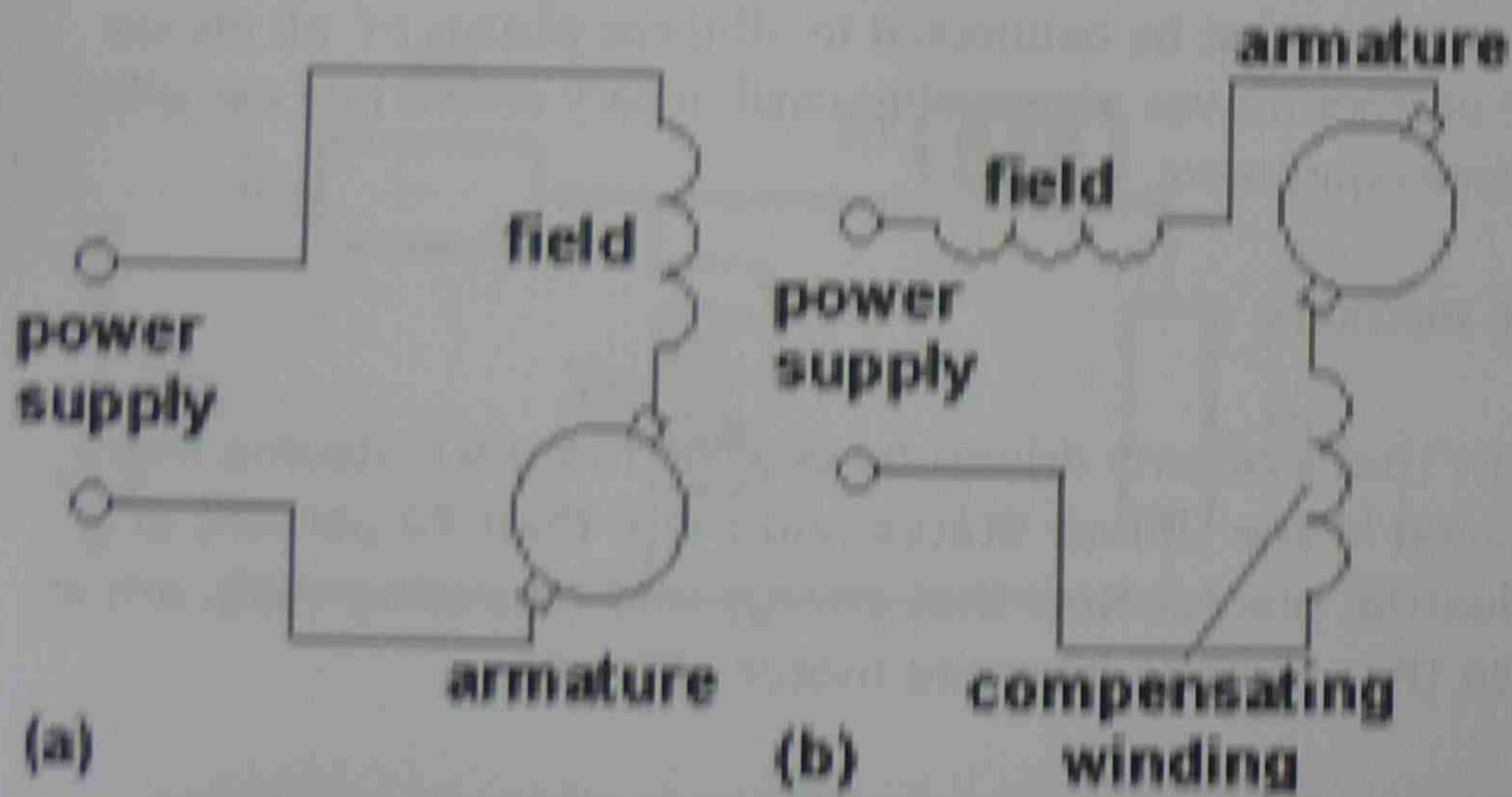
(b) Permanently split capacitor motor



(c) Shaded pole motor



(d) Universal motor



Q91. Compare single phase and three phase motor.

There are always a couple copper coils around part of the frame. when running, these are very hot because there is an induced current in them. if you remove them, 2 things happen.

1. the motor will spin in either direction.

2. it will be stronger.

unfortunately, there are relatively few applications in which the direction of spin is irrelevant.

it's kind of like if you had a bicycle where you could push or pull straight on one pedal, but you couldn't see which direction you were pushing. Once it gets going, you're okay, but getting started is chancy.

with a 3 phase motor, you don't have that problem. there's always 2 sets of windings for which your "pedal" cannot be at the top or bottom of the stroke.

what that does is provide nearly even power throughout the rotation cycle.

The most common type of 3 phase electrical load is the *3 phase electric motor*. A 3 phase motor is more compact and less costly than a 1-phase motor of the same voltage class and rating; also 1-phase AC motors above 10 HP (7.5 kW) are not as efficient and thus not usually manufactured. A 3 phase induction motor has a simple design, inherently high starting torque, and high efficiency. Such motors are applied in industry for 3 phase pumps, fans, blowers, compressors, conveyor drives, and many other types of 3 phase motor-driven equipment. There are a lot of benefits to using a 3 phase electric motor over a single phase electric motor.

Three-phase loads such as larger motors must be connected to all three phases of all phases can suffer damage as the reactive current moves across abnormal rotary converters can allow satisfactory operation of three-phase equipment.

Q92. Describe motor maintenance methods.

Widely publicized estimates show that systems driven by electric motors consume more than half of the electricity produced in the United States and more than 70 percent of the electricity used in many industrial plants. Now that energy and operating costs are at a premium, it makes more sense than ever to increase motor efficiency.

Many facilities find it makes sense to divide their motor efficiency strategy into three phases:

- Overall assessment
- Immediate improvements
- Long-term
- Survey and document how many motors, at what age, horsepower and ratings, with what level of controls are present in your facility.
- Identify the highest and most critical loads.

- For those key units, use a power logger to evaluate their energy consumption (power draw).

This will give you a general energy-consumption map for motors in your facility.

1. Changes to the units and to unit operation
2. Repairs

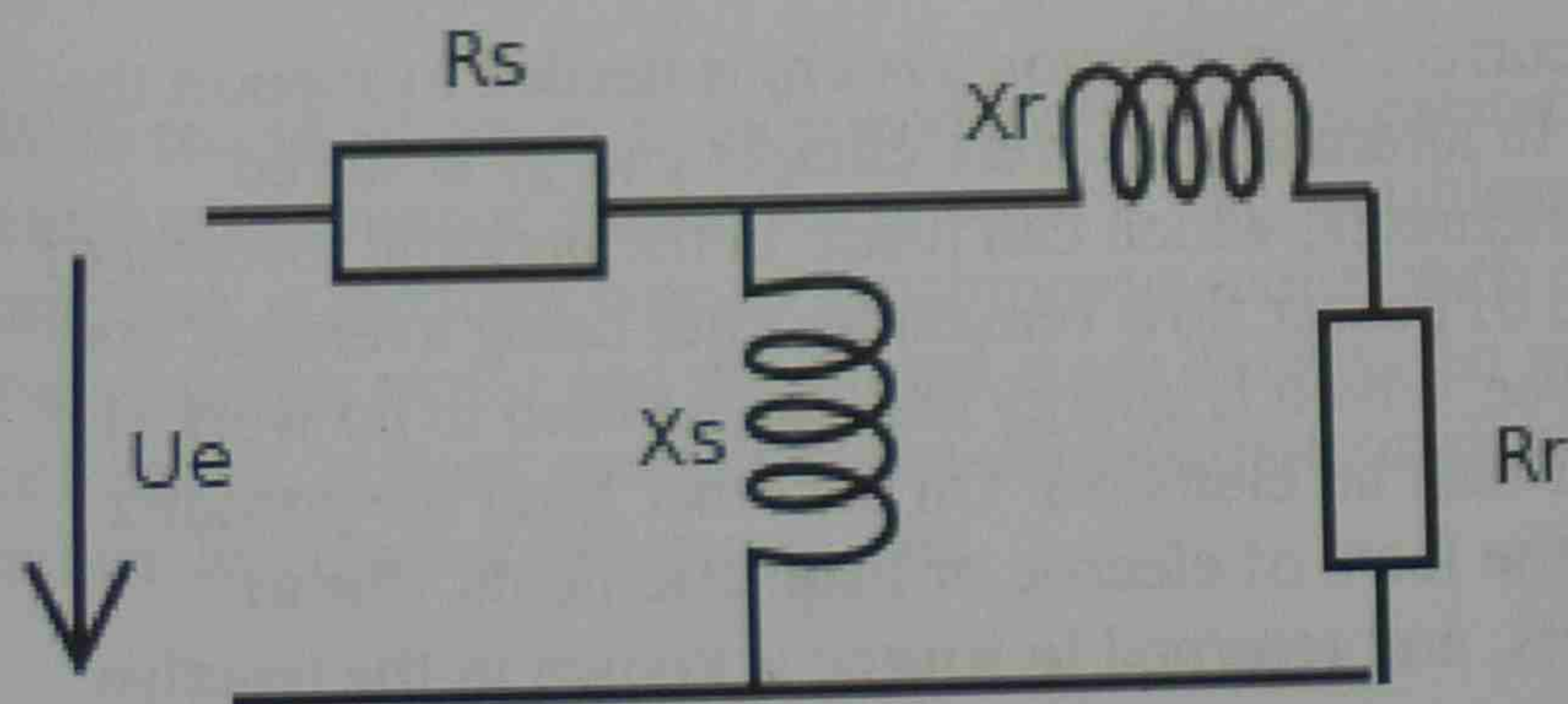
Changes to the units may include replacing some motors with higher-efficiency or better-sized models, adding controls to others to right-size output, and rescheduling which motors run when compared to demand and utility rates.

To determine whether any of these changes make sense in your facility, use a motor efficiency calculator such as MotorMaster+ from the U.S. Department of Energy. It can help you calculate savings per motor and per efficiency step.

Otherwise, there are three inspection points that you should make to all motors that you intend to keep operational:

1. Voltage unbalance
2. Current unbalance
3. Power factor

Q93. Sketch equivalent circuit of single phase motor



Q95. How will you determine synchronous impedance?

The voltage E_z which forces the current I_1 through the impedance of the motor windings produces a voltage drop $I_1 Z_s$. The impedance Z_s is called the *synchronous impedance* and is composed of two parts. One part is $R_a + jX_a$, which is the resistance and leakage reactance of the winding. The other part is X_r , which is not a reactance in the usual sense but is the result of the effect of the stator ampere-turns on the total flux of the motor. This effect is called *armature reaction* and its magnitude depends almost altogether on the angle by which the rotor poles lag the stator poles in space. It is apparent then that X_r depends on both the magnitude of the motor load and the motor power factor. If the mmf of the armature reaction tends to decrease the total flux, its effect is the same as additional reactance drop; and, therefore, X_r and X_a are commonly combined and the result is called X_s . The value of Z_s is composed of both parts. Thus,

$$Z_s = R_a + jX_a + jX_r$$

To determine Z_s experimentally, the machine is driven at synchronous speed without excitation. The polyphase winding is short-circuited through three ammeters, one in each lead, to measure the current I_p per phase. A small direct current is then used to magnetize the field poles to the point where the three ammeters show full-load rated current. From the open-circuit saturation curve of the machine, the voltage E_p per phase is found corresponding to the direct current used. The synchronous impedance, in ohms, is then $Z_s = E_p / I_p$. With the polyphase winding short-circuited, all of E_p is used to force I_p through the total impedance Z_s of the machine. Refinements of this procedure are necessary if Z_s must be determined accurately for some particular condition of loading.

Q97. Explain excitation and reactive power.

Reactive power flow on the alternating current transmission system is needed to support the transfer of real power over the network. In alternating current circuits energy is stored temporarily in inductive and capacitive elements, which can result in the periodic reversal of the direction of energy flow. The portion of power flow remaining after being averaged over a complete AC waveform is the real power, which is energy that can be used to do work (for example overcome friction in a motor, or heat an element). On the other hand the portion of power flow that is temporarily stored in the form of electric or magnetic fields, due to inductive and capacitive network elements, and returned to source is known as the reactive power.

AC connected devices that store energy in the form of a magnetic field include inductive devices called reactors, which consist of a large coil of wire. When a voltage is initially placed across the coil a magnetic field builds up, and it takes a period of time for the current to reach full value. This causes the current to lag the voltage in phase, and hence these devices are said to absorb reactive power.

A capacitor is an AC device that stores energy in the form of an electric field. When current is driven through the capacitor, it takes a period of time for charge to build up to produce the full voltage difference. On an AC network the voltage across a capacitor is always changing –

the capacitor will oppose this change causing the voltage to lag behind the current. In other words the current leads the voltage in phase, and hence these devices are said to generate reactive power.

Energy stored in capacitive or inductive elements of the network give rise to reactive power flow. Reactive power flow strongly influences the voltage levels across the network. Voltage levels and reactive power flow must be carefully controlled to allow a power system to be operated within acceptable limits.

Variable-speed constant-frequency generating systems are used in wind power, hydroelectric power, aerospace, and naval power generation applications to enhance efficiency and reduce friction. In these applications, an attractive candidate is the slip power recovery system comprising a doubly excited induction machine or doubly excited brushless reluctance machine and PWM power converters with a DC link. In this paper, a flexible active and reactive power control strategy is developed, such that the optimal torque-speed profile of the turbine can be followed and overall reactive power can be controlled, while the machine copper losses have been minimized. At the same time, harmonics injected into the power network have also been minimized. In this manner, the system can function as both a highly-efficient power generator and a flexible reactive power compensator.

Q98.Explain excitation methods.

There are two major types of synchronous motors: 'non-excited' and 'direct-current excited', which have no self-starting capability to reach synchronism without extra excitation means, such as electronic control or induction.

With recent advances in independent brushless excitation control of the rotor winding set that eliminates reliance on slip for operation, the 'brushless wound-rotor doubly-fed electric machine' is the third type of synchronous motor with all the theoretical qualities of the synchronous motor and the wound-rotor doubly-fed motor combined, such as power factor correction, highest power density, highest potential torque density, low cost electronic controller, highest efficiency, etc.

Non-excited motors

These are manufactured in permanent magnet, reluctance and hysteresis designs. Reluctance and hysteresis designs employ a self-starting circuit and require no external excitation supply. Permanent magnet designs require electronic control for practical operation (see Permanent magnet synchronous generator).

Reluctance motor designs have ratings that range from sub-fractional to about 30 hp. Sub-fractional horsepower motors have low torque, and are generally used for instrumentation applications. Moderate torque, integral horsepower motors use squirrel cage construction with toothed rotors. When used with an adjustable frequency power supply, all motors in the

drive system can be controlled at exactly the same speed. The power supply frequency determines motor operating speed.

Hysteresis motors are manufactured in sub-fractional horsepower ratings, primarily as servomotors and timing motors. More expensive than the reluctance type, hysteresis motors are used where precise constant speed is required.

Synchronous motors may be excited in several ways:

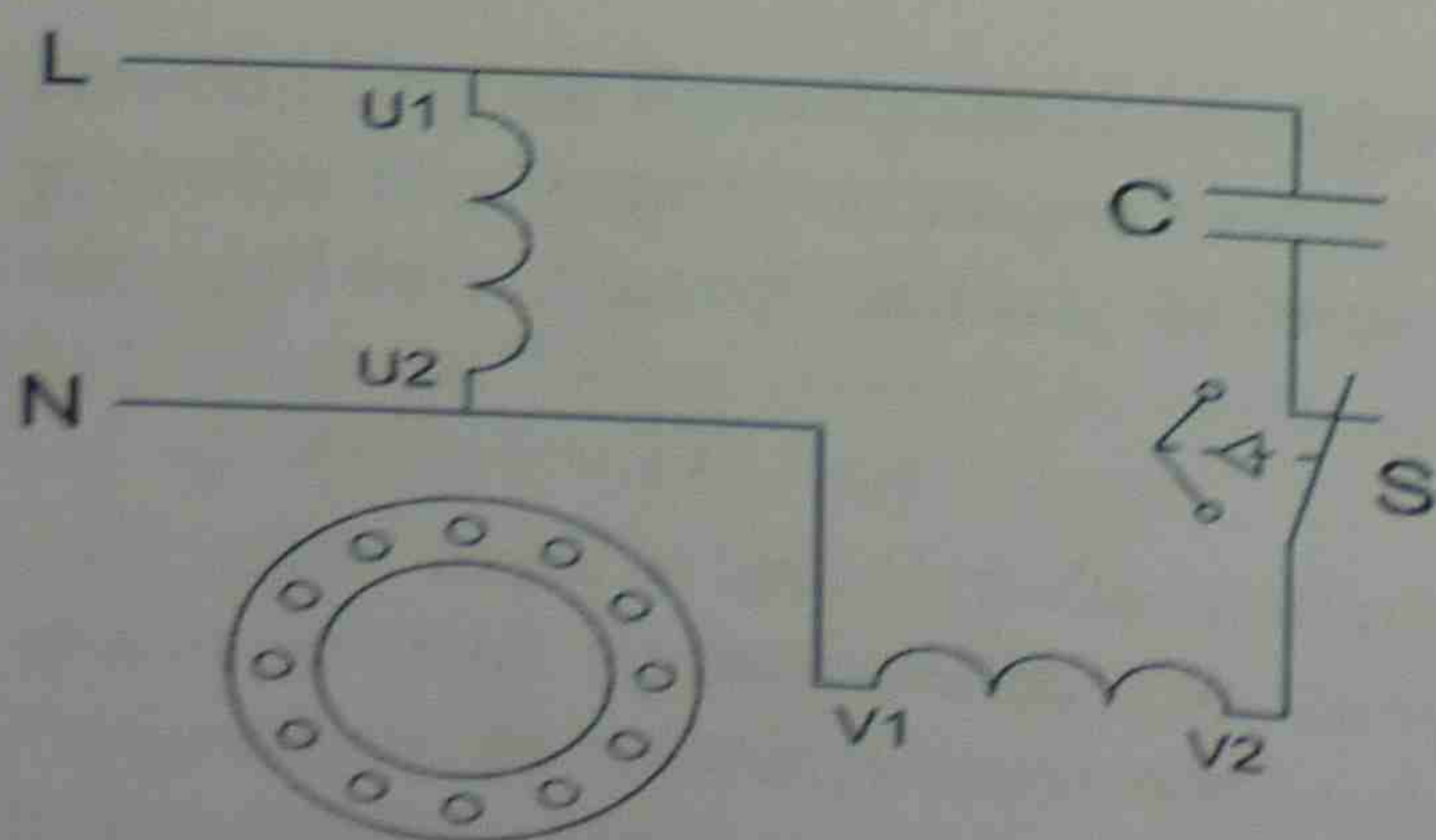
1. A small Exciter-dynamo mounted on the same shaft
2. Shell-commutator
3. Series-excitation
4. Shunt-excitation
5. Armature winding plus continuous-current commutator

Q99.Explain the connection of synchronous motor with sketch.

synchronous electric motor is an AC motor distinguished by a rotor spinning with coils passing magnets at the same rate as the power supply frequency and resulting rotating magnetic field which drives it.

Another way of saying this is that it does not rely on slip under usual operating conditions and as a result, produces torque at synchronous speed. Synchronous motors can be contrasted with an induction motor, which must slip in order to produce torque. They operate synchronously with line frequency. As with squirrel-cage induction motors, speed is determined by the number of pairs of poles and the line frequency.

Synchronous motors are available in sub-fractional **self-excited** sizes to high-horsepower **direct-current excited** industrial sizes. In the fractional horsepower range, most synchronous motors are used where precise constant speed is required. In high-horsepower industrial sizes, the synchronous motor provides two important functions. First, it is a highly efficient means of converting ac energy to work. Second, it can operate at leading or unity power factor and thereby provide power-factor correction.



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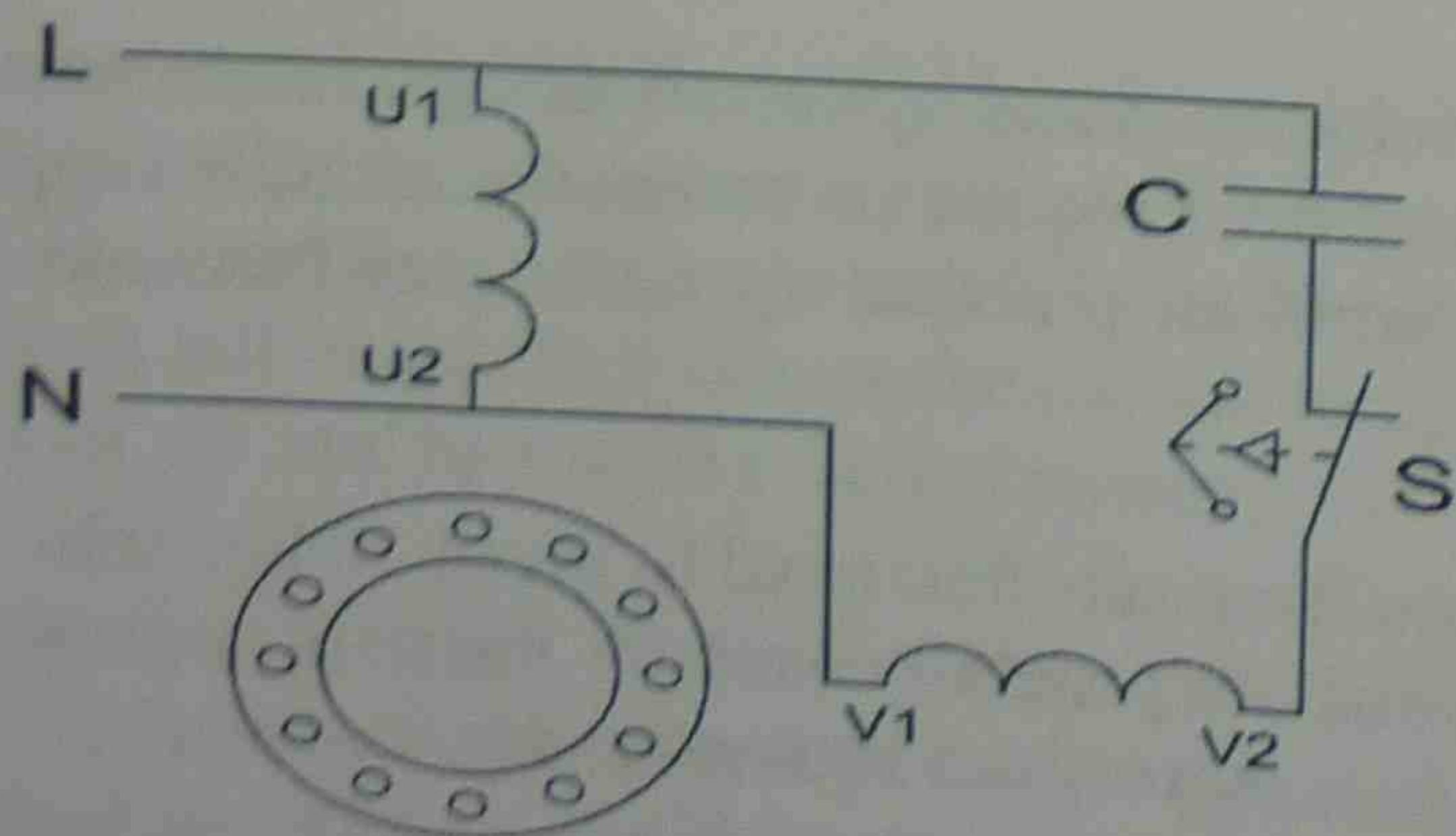
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Plot representing the three phase currents displaced by 120 electrical degrees

